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RPP-23405, Rev. 1

Tank Farm Vadose Zone Contamination Volume Estimates

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Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

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Abstract:
This report provides a summary of volume estimates and dates for single-shell tank leaks, waste-loss events in or near a tank and unplanned releases within designated waste management areas in the Hanford Tank Farms. These volume estimates will be used in the RCRA Facility Investigations report for single-shell tank waste management areas and in support of single-shell tank performance assessments.

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RPP-23405
Revision 1

TANK FARM VADOSE ZONE CONTAMINATION VOLUME ESTIMATES

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Acronyms and Abbreviations

BBI	best-basis inventory
bgs	below ground surface
CMS	Corrective Measures Study
DOE	U.S. Department of Energy
HDW	Hanford Defined Waste
HLW	high-level waste
LAW	low-activity waste
PAW	PUREX acid waste
PUREX	Plutonium-Uranium Extraction
R1	REDOX waste generated between 1952 and 1957
REDOX	reduction and oxidation
RFI	RCRA Facility Investigations
SIM	Soil Inventory Model
SST	single-shell tank
TBP	tributyl phosphate
TWINS	*Tank Waste Information Network System*
UPR	unplanned release
WIDS	*Waste Information Data System*
WMA	Waste Management Area

Units

Ci	curies
cpm	counts per minute
ft	feet
gal	gallons
in.	inch(es)
kgal	thousand gallons
Mgal	million gallons
pCi	picocuries
psi	pounds per square inch

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1.0 INTRODUCTION

This report provides a summary of volume estimates and dates for Single-Shell Tank (SST) leaks, waste-loss events in or near a tank and Unplanned Releases (UPRs) within designated Waste Management Areas (WMA) in the Hanford Site Tank Farms. These volume estimates will be used in support of the Resource Conservation and Recovery Act (RCRA) Facility Investigations (RFI) report for Single-Shell Tank (SST) WMAs and in support of SST performance assessments.

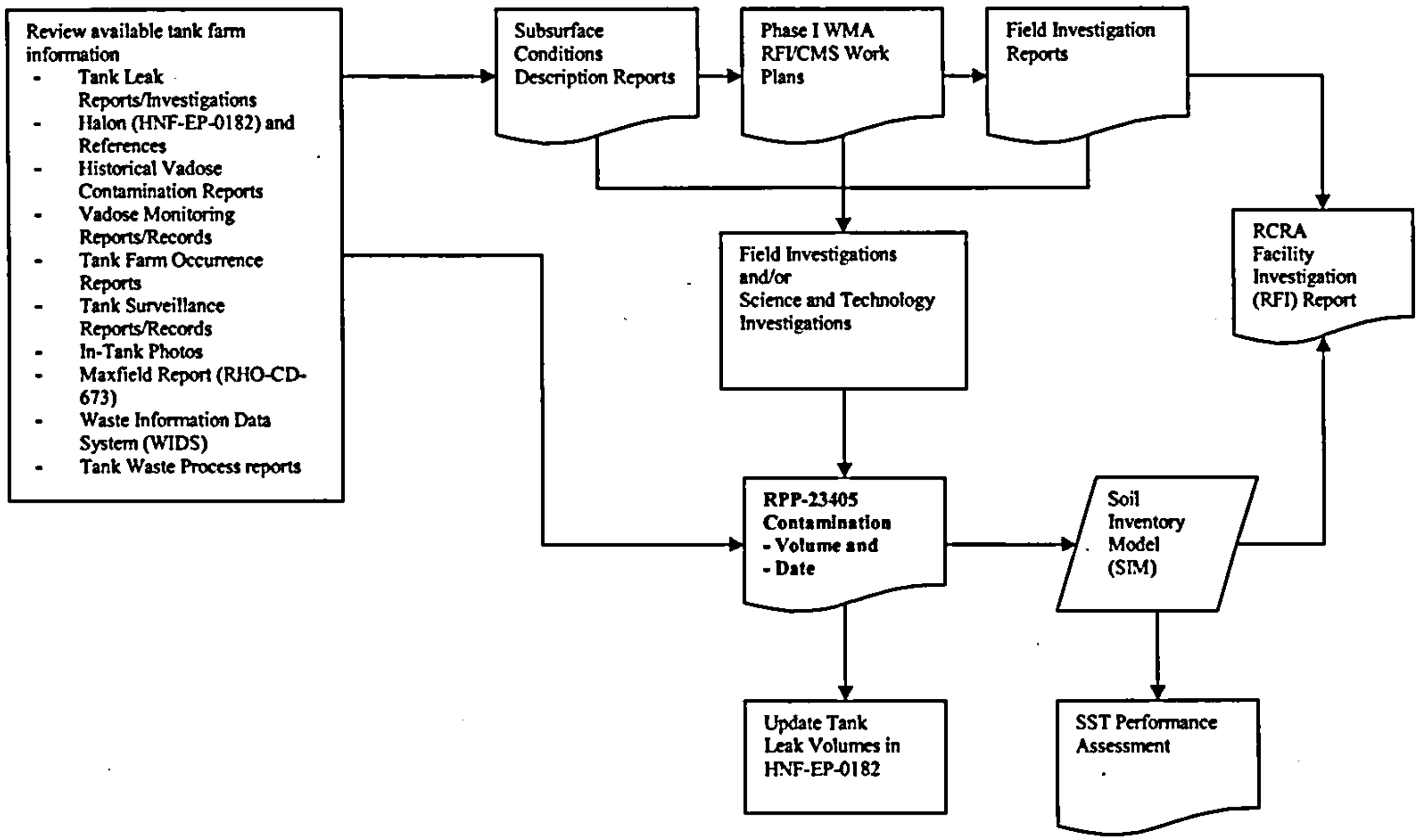
The RCRA Facility Investigations/Corrective Measures Study (RFI/CMS) work plan provides the overall framework to guide groundwater and vadose zone investigation and decision making for single-shell tank WMAs at the Hanford Site. The approved *Hanford Federal Facility Agreement and Consent Order*[1] Change Package M-45-98-03 establishes that the RFI supports the development and implementation of interim measures and interim corrective measures, and supports single-shell tank waste retrieval and closure activities through integration with other projects (e.g., Groundwater Protection Program [formerly the Groundwater/Vadose Zone Integration Project] and Single-Shell Tank Retrieval).

Volume estimates and tank waste composition dates in this document are inputs to the Hanford Site Wide Soil Inventory Model (SIM) which calculates vadose zone contaminant inventories in support of Performance Assessments and the RFI report (BHI-01496, *Groundwater/Vadose Zone Integration Project: Hanford Soil Inventory Model*). The SIM multiplies the contaminant volume for a waste-loss event by an estimated waste composition at the time of the event to derive an inventory. The SST WMA contaminant concentrations in SIM are from Hanford Defined Waste (HDW) Model estimates (RPP-19822, *Hanford Defined Waste Model – Revision 5*). The HDW Model uses a mass balance and mixing model to estimate waste composition by tank and year. Documentation for the SIM will be prepared to reflect these waste volumes and dates, provide a technical basis for inventory estimates, define assumptions for composition estimates and uncertainty distributions used, and describe SIM verification and validation.

Tank farm vadose zone investigations are ongoing. The volume estimates presented in this report will be updated as additional characterization data become available through the RFI/CMS process and a better understanding of vadose zone contamination is developed. The tank leak loss estimates in the *Waste Tank Summary Report* (HNF-EP-0182) and the SIM results and documentation will be updated as needed consistent with this report. Figure 1-1 illustrates the role of this report in developing the RFI.

[1] Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Figure 1-1. Role of RPP-23405 in Developing the RFI Report



1.1 BACKGROUND

Over the past decade, there has been a significant effort by the Hanford Site tank farm vadose zone program to better understand and quantify vadose zone contamination in and around the single-shell tanks (SST). This report summarizes the following vadose work:

- Spectral gamma logging of all available drywells in the SST farms
- Analysis of historical gross gamma logging data collected from 1974 through 1994 in the SST farms
- Review of available historical tank farm operational records, surveillance records, tank leak documentation, and field characterization data from a number of the SST farms
- Science & Technology investigations that enhance the understanding of the interactions between tank waste materials and Hanford Site soils.

The Hanford Site tank farm vadose zone program is managed by CH2M HILL Hanford Group, Inc. (CH2M HILL) under the direction of the U.S. Department of Energy (DOE) Office of River Protection and functions through a multi-contractor multi-disciplined approach. Tank farm vadose zone activities are integrated with other subsurface characterization efforts through the DOE Groundwater Protection Program managed by Fluor Hanford. A major focus of the program has been to quantify the inventories of chemicals and radionuclides that were intentionally or accidentally discharged to the vadose zone in the 200 Areas. The tank/ancillary equipment leak volume estimates presented in this report were based on the following vadose zone program documents:

- RPP-6285, *Inventory Estimates for Single-Shell Tank Leaks in S and SX Tank Farms*
- RPP-7218, *Preliminary Inventory Estimates for Single-Shell Tank Leaks in T, TX, and TY Tank Farms*
- RPP-7389, *Preliminary Inventory Estimates for Single-Shell Tank Leaks in B, BX, and BY Tank Farms*
- RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Area*
- RPP-15808, *Subsurface Conditions Description of the U Waste Management Areas*

1.2 SCOPE

The two groups of soil contamination volume estimates presented in this report are: (1) tank/ancillary equipment leak volumes, and (2) volume of UPRs or surface contamination within the SST farms.

This report includes tank leak volumes for the 67 SSTs classified as assumed leakers in HNF-EP-0182. All of the 82 SSTs classified in HNF-EP-0182 as "sound" were also assessed by the vadose team. Tank 241-C-105 was the only "sound" tank for which a leak volume estimate was merited, due to the presence of vadose contamination.

In addition to tank leaks or spills from tanks/ancillary equipment another source of contamination in the tank farm is unplanned releases (UPRs). The UPR estimates shown in this report are those reported in WIDS as of July 1, 2005. Because UPRs were assumed to have a much smaller inventory compared to tank leaks, except for C-Farm studies, the vadose program has done little work to quantify or validate current UPR estimates. Near surface contamination information and needs will be addressed in the RFI. This report and vadose inventory estimates will be updated as additional information is obtained.

Note: ancillary equipment are defined in this document as equipment or structures such as cascade lines, transfer lines or pump pits connected to or directly associated with an SST that may be attributed to a tank leak (eg. cascade lines, transfer lines, pump pits). Except for UPRs, an assessment of other tank farm infrastructure leaks is expected to be minor and has not been performed as part of WMA investigations.

The volume estimates presented are "best" estimates of the volume of contaminated fluid lost to the vadose zone. Upper bounds for selected leak volumes and inventories will be incorporated into sensitivity studies in performance assessments and the RFI report.

Sections 2.0 and 3.0 focus on assumed or confirmed leaking tanks (HNF-EP-0182, *Waste Tank Summary Report for Month Ending March 31, 2005*) in the SST farms. Tank leaks are a major source of vadose zone contamination in the tank farms and have been the focus of vadose zone contamination studies. Section 2.0 provides tables showing leak volume estimates from the tanks or ancillary tank equipment assumed to contribute to the vadose zone inventory. A synopsis describing the basis for tank or ancillary equipment leak volume estimates is presented in Section 3.0. More detailed discussions are presented in reports referenced. For some tanks, little or no basis for previous leak volume estimates was found; however, some tank leak events and volume estimates are well documented. Tank leak estimates were categorized in 1 of 4 groups for uncertainty estimates to be defined and used in SIM:

Group1 - Well known and documented leaks, estimates increased or remained the same.

Group 2 - Small leaks, no change from previous leak volume estimates.

Group 3 – The leak volume was reduced. Evidence in the vadose zone does not support previous leak volume estimates.

Group 4 - No basis for a leak volume estimate and assumed negligible.

The following items were not addressed:

- Tank/ancillary equipment leak volumes do not include tank waste residuals or residuals in pipelines or ancillary equipment.
- While tank leak volume estimates were revised for some of the tanks and no inventory basis was found for others, previous tank integrity classifications were not changed. Change to tank integrity classifications requires implementing the tank leak assessment process (TFC-ENG-CHEM-D-42, "Tank Leak Assessment Process") and is beyond the scope of this report.
- Crib and trench discharges are mostly outside tank farm WMA boundaries and are not discussed in this report. Crib and trench discharges will be addressed in future Hanford Site integration studies.

A list of documented UPR and near-surface contamination volume estimates in the SST farms is presented in Section 4.0. The near-surface losses presented in this report are UPRs included in WIDS as of July 1, 2005. Although extensive surface contamination is found in some farms, the volume of waste from UPRs generally is a small fraction of the total volume from tank leaks and ancillary equipment.

1.3 PROCESS

The single-shell leak information included in *Waste Tank Summary Report* (HNF-EP-0182) focuses on the volumes of waste assumed to have leaked for tanks listed as "confirmed or suspected leakers". Early on in the development of data requirements for the characterization of environmental impacts of past single-shell tank leaks, the need for tank leak inventory estimates was identified (HNF-2603, "*A Summary and Evaluation of Hanford Site Tank Farm Subsurface Contamination*"). The extensive workscope completed by Agnew et al. (LA-UR-96-3860) provided an approach that was directly applicable to estimating single-shell tank leak inventories. Agnew's Hanford Defined Waste (HDW) Model provided an estimate of waste compositions in each Hanford single- and double-shell waste storage tank as a function of time. Such data could then be coupled with dates of known tank leaks and leak volumes to develop approximations of chemicals and radionuclides lost during a leak event. This process is shown schematically in Figure 1-2.

A major assumption in developing leak inventory estimates was that the HDW Model, which coupled chemical processing flow sheet data with waste transfer records to estimate tank waste compositions over time, provided a reasonable waste composition at the time of waste loss events. More problematic were the estimates of the "leak date" and "leak volume". The *Waste Tank Summary Report* provided a "confirmed leak date" and an estimated leak volume. In many cases the "confirmed leak date" was considerably different from the most likely leak date and a number of "leak volumes" were highly uncertain. Thus, all available information on single-shell tank leaks was re-evaluated.

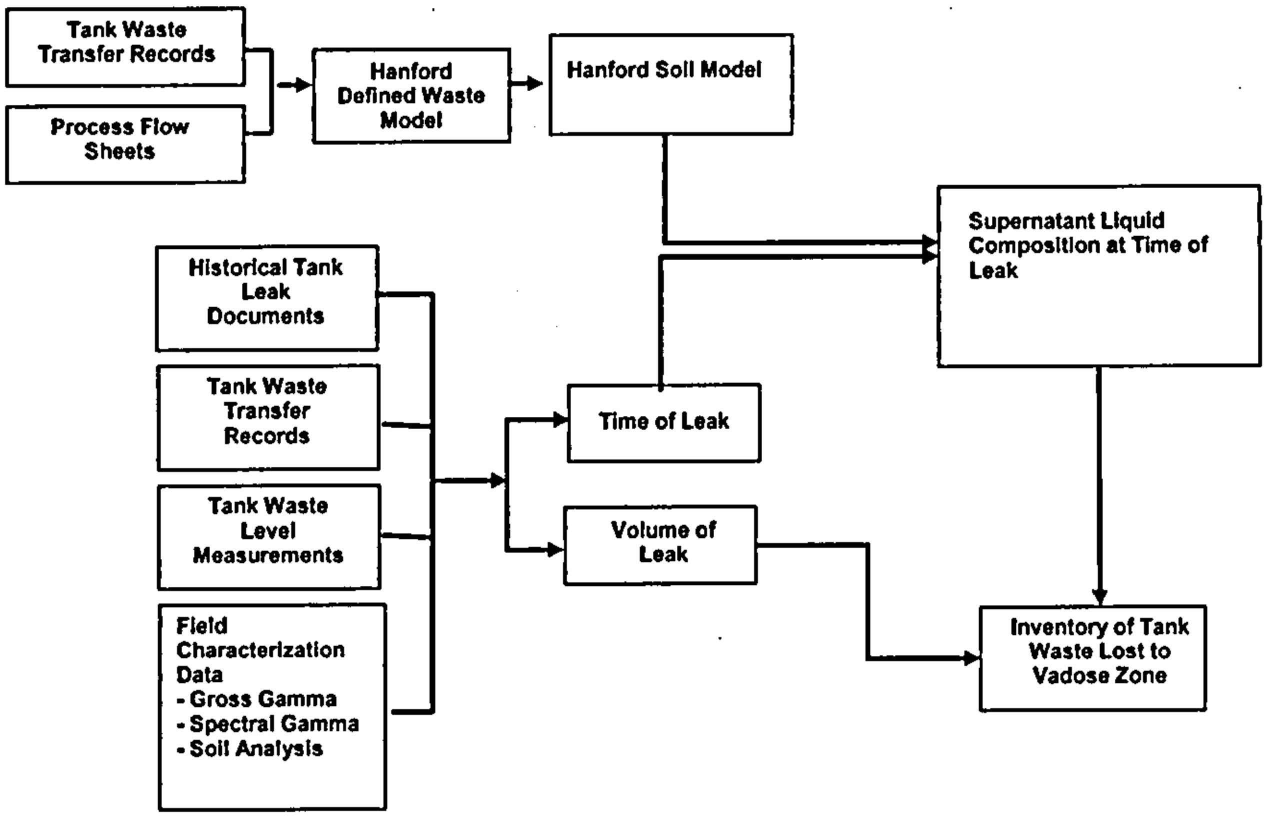
This re-evaluation examined all of the available tank integrity information for each of the 149 single-shell tanks. The major effort in the 1990s to declassify and release to the public large numbers of Hanford historical documents greatly facilitated the reevaluation of single-shell tank leaks, as did the completion of a systematic re-logging of single-shell tank farm drywells using spectral gamma techniques.

The goal was to correlate historical estimates of single-shell tank leaks with information from other sources. For example, the loss of large volumes of high-activity waste would necessarily lead to significant residual cesium-137 contamination in the soil. Lack of such cesium-137 contamination led to careful reassessment of historical data supporting the original assignment of a leak volume. Specific examples are dicussed in Sections 3.1 to 3.4.

Near surface contamination volumes presented in Section 4.0 were a compilation of UPRs included in the WIDS database as of July 2005 and located within designated WMAs. Volumes shown were those specified in the WIDS or derived based on information in WIDS. Waste compositions for tanks and UPRs and inventory calculations will be presented in the SIM report.

Many of the UPRs were airborne particulate releases or were assumed to be low volume sprays. There was no technical basis for a volume estimate for these UPRs and no volume estimates were presented in the WIDS; therefore, the inventories for these UPRs were assumed to be negligible and are not included. Other than work in C-Farm, there has been little effort in addition to the data presented in WIDS to further characterize or quantify surface contamination within the Tank Farms. As for tank leaks, the UPR estimates presented in this report will be updated as sites are further characterized and as new information is obtained. Characterization plans are or will be identified in RFI phase 1 documents.

Figure 1-2. Historical Tank Leak Inventory Estimates Flow Chart



2.0 TANK/ANCILLARY EQUIPMENT LEAK ESTIMATES IN SINGLE-SHELL TANK FARMS

Sixty-seven of Hanford's 149 SSTs are listed as "confirmed or assumed leakers" in HNF-EP-0182. Much of the tank leak information in HNF-EP-0182 was compiled in the late 1980s and reflects the state of knowledge at that point in time. Leak volume estimates are of varying quality; for example, the leak volumes for SSTs SX-113, SX-115, and T-106 are well documented; however, 19 tanks have unexplained liquid-level decreases and no technical basis for a leak volume or inventory estimate.

Some of the tank leaks listed in HNF-EP-0182 (Rev. 199) may be associated with waste transfer system waste-loss events and tank overfill events and appear to be associated with ancillary equipment rather than failure of the tank itself. These events are described in RPP-6285; RPP-7218; RPP-7389; RPP-7884, *Field Investigation Report for Waste Management Area S-SX*; RPP-10098, *Field Investigation Report for Waste Management Area B/BX/BY*; RPP-15808, and summarized in Section 3.0.

Over the past decade, vadose investigations have focused on developing a better understanding of major SST leaks and the potential impacts of SST leaks on groundwater quality by reviewing vadose and tank process data for each of the 149 SSTs. The vadose zone team efforts focused on defining the impacts of "tank farm operations" on the vadose zone, including past leaks from SSTs, SST overfills, and piping and infrastructure waste-loss events.

The vadose zone characterization effort included field drilling, sampling, and soil analysis in multiple SST farms coupled with research and review of historical process records and gamma logging data. These efforts integrated information from a number of Hanford-related projects and focused on evaluating the tank leak events that contribute the bulk of subsurface contamination. The following sources were reviewed for this report:

- Spectral gamma logging data from drywells
- Analysis of historical gross gamma logging data collected from 1974 through 1994
- Review of historical tank farm operations and surveillance records
- Review of historical process chemistry records from Hanford Site facilities
- Results from vadose zone characterization in WMA S/SX
- Studies of cesium sorption chemistry in Hanford Site soils
- Studies of moisture movement and unsaturated flow characteristics in Hanford Site soils.

2.1 GROSS GAMMA AND SPECTRAL GAMMA LOGGING DATA

Baseline spectral gamma logging has been completed for all of the drywells within each of the 12 SST farms as well as assessments of the historical gross gamma logging data from each SST farm. Results of the baseline spectral gamma logging project are summarized in 12 MACTEC-ERS spectral gamma logging tank farm reports (one for each SST farm) (hereafter referred to collectively as the MACTEC reports). Analysis and summaries of the gross gamma logging data also are reported by tank farm. Reference information for the MACTEC reports is listed in Table 2-1.

Table 2-1. Spectral Gamma Logging Tank Farm Reports. (2 sheets)

Report	Title
GJO-HAN-6/GJO-96-2-TAR	*Vadose Zone Characterization Project at the Hanford Tank Farms, BY Tank Farm Report*
GJO-HAN-8/GJO-97-1-TAR	*Vadose Zone Characterization Project at the Hanford Tank Farms, U Tank Farm Report*
GJO-HAN-11/GJO-97-13-TARA	*Hanford Tank Farms Vadose Zone, TX Tank Farm Report*
GJO-HAN-12/GJO-97-14-TARA	*Addendum to the AX Tank Farm Report*
GJO-HAN-16/GJO-97-30-TAR	*Hanford Tank Farms Vadose Zone: TY Tank Farm Report*
GJO-HAN-18/GJO-98-39-TARA	*Hanford Tank Farms Vadose Zone: C Tank Farm Report*
GJO-HAN-19/GJO-98-40-TAR	*Hanford Tank Farms Vadose Zone: BX Tank Farm Report*
GJO-HAN-23/GJO-98-64-TAR	*Hanford Tank Farms Vadose Zone: A Tank Farm Report*
GJO-HAN-27/GJO-99-101-TARA	*Hanford Tank Farms Vadose Zone: T Tank Farm Report*
GJO-HAN-28/GJO-99-113-TAR	*Hanford Tank Farms Vadose Zone: B Tank Farm Report*
GJO-HAN-17/GJO-97-31-TAR	*Hanford Tank Farms Vadose Zone: S Tank Farm Report*
GJPO-HAN-4/DOE/ID/12584-268	*Vadose Zone Characterization Project at the Hanford Tank Farms, SX Tank Farm Report*
RPP-8820, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-A Tank Farm – 200 East*
RPP-8821, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-AX Tank Farm – 200 East*
HNF-5433, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-B Tank Farm – 200 East*
HNF-3531, Rev. 0	*Analysis of Historical Gross Gamma Logging Data from BX Tank Farm*
HNF-3532, Rev. 0	*Analysis of Historical Gross Gamma Logging from BY Tank Farm*
RPP-8321, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logging Logs for the 241-C Tank Farm – 200 East Area*
HNF-4220, Rev. 0	*Analysis and Summary of Historical Dry Well Gamma Logs for S Tank*

Table 2-1. Spectral Gamma Logging
Tank Farm Reports. (2 sheets)

Report	Title
	Farm – 200 West
HNF-3136, Rev. 0	*Analysis Techniques and Monitoring Results, 241-SX Drywell Surveillance Logs*
RPP-6088, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-T Tank Farm – 200 West*
RPP-6353, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-TX Tank Farm – 200 West*
HNF-3831, Rev. 0	*Analysis of Historical Gross Gamma Logging Data from 241-TY Tank Farm*
RPP-7729, Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logging Logs for the 241-U Tank Farm – 200 West Area*

2.2 SINGLE-SHELL TANK FARM FIELD INVESTIGATIONS

A Summary and Evaluation of Hanford Site Tank Farm Subsurface Contamination (HNF-2603) provides the technical basis for the tank farm vadose investigations. Since the publication of HNF-2603, additional technical documents have been released that track progress in the tank farm vadose characterization efforts (RPP-7884 and RPP-10098). An active drilling program is underway in WMAs T, TX-TY, and C (RPP-7578, *Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMAs T, TX and TY*) as well as planning for field investigations in the C, A, AX, and U tank farms (RPP-14430).

2.3 RELATIONSHIP BETWEEN LOGGING DATA AND TANK LEAKS

The baseline spectral gamma logging data collected from drywells within the SST farms provide a window for interpreting tank leak information. The relationship between the leak status of SSTs and spectral gamma logging data in nearby drywells is qualitative. However, both the depth of gamma activity and its intensity provide some ability to distinguish between tank losses and losses associated with piping or tank overfills and provides a basis to assess the impact of tank liquid-level decreases to the vadose zone.

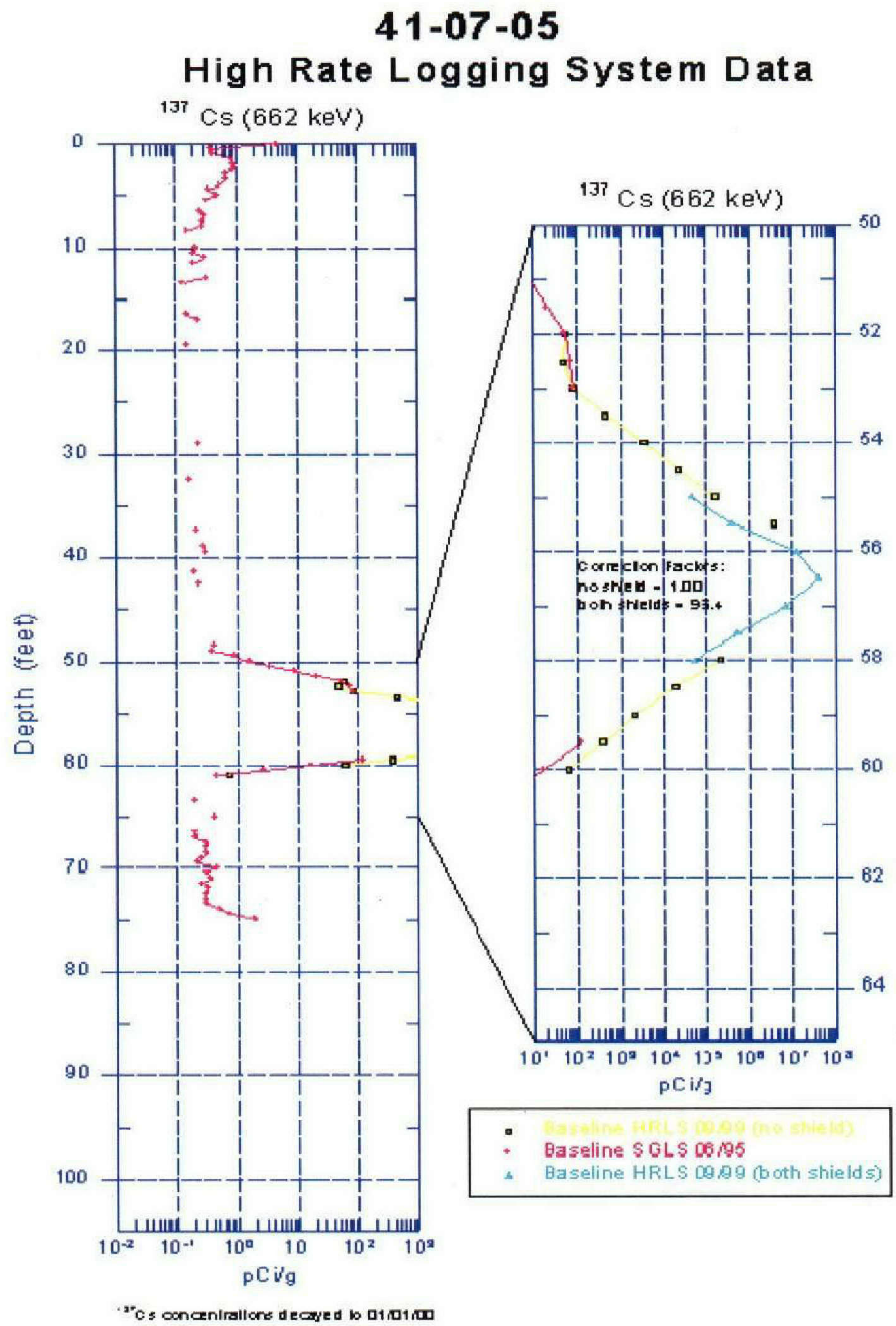
Most easily distinguished are cases where waste volume decreases correspond to high ^{137}Cs activity in one or more nearby drywells. In these cases, ^{137}Cs activity is often greater than 10^7 pCi/g (Figure 2-1). Depending on the waste type present, there are frequently other gamma emitters at much lower concentrations. If the high ^{137}Cs activity zones appear at or near the levels of the waste transfer lines or SST spare inlet ports, then this may be evidence of a piping leak or tank overfill event as the origin of the contamination. Cesium-137 activity on the order of 10^4 pCi/g or higher beginning near the base of the tank (see NOTE 1) is a strong indication of a tank leak. Lower cesium activity further away from a tank is much more difficult to interpret.

NOTE 1 – An indicator value of 10^4 pCi/g ^{137}Cs is a judgment call. The rationale for selecting a high ^{137}Cs value is based on cesium sorption chemistry in Hanford Site soils. For background information on this subject refer to RPP-7884, Appendix D. Work by Zachara et al. (2002) ("Sorption of Cs^+ to Micaceous Subsurface Sediments from the Hanford Site") shows that cesium is strongly sorbed on Hanford Site soils. Thus, a dilute solution of ^{137}Cs discharged to the same point in the soil column would lead to high-activity levels in the soil if sufficient volumes were discharged. Based on the extensive spectral gamma logging database and a limited soil analysis data set, the "effective ^{137}Cs sorption capacity" of Hanford Site soils appears to be in the range of 10^7 to 10^8 pCi/g. The mechanism of cesium movement in the subsurface appears to depend on saturating the available active sites on the soil particles prior to plume movement. This mechanism is constrained by the sorption kinetics; therefore, high ^{137}Cs activity in soil penetrated by sufficient volumes of waste containing ^{137}Cs is expected.

Low levels of ^{137}Cs contamination are common in drywells around most SSTs. Open boreholes may have provided a pathway for contamination to enter the well casing, and in some cases, the unsealed boreholes could have provided a pathway for contamination to move downward. In addition, the compacted base on the original tank farm excavation provided a region for liquids to pond and move laterally. The cesium-sorption chemistry predicts that the ^{137}Cs is in a highly concentrated plume with sharp activity drops at the edge of the plume (RPP-7884). Thus, when low ^{137}Cs activity is reported in one of the drywells it appears there are only two reasonable explanations: (1) Either the drywell is sitting on the edge of a high-activity ^{137}Cs plume, or (2) the contamination was the result of a lower activity gamma contamination spread from routine operations. Distinguishing between the two options requires an assessment of other information such as waste transfer and waste level records, waste type in the tank, documented leak history, and data from nearby drywells.

An understanding of the waste type involved in any type of release to the soil column is critical in developing a useful inventory estimate. Within reason, the type of waste lost is more important than the volume of waste lost. The ^{137}Cs concentration was as high as 30 Ci/gal in the Plutonium-Uranium Extraction (PUREX) high-level waste (HLW) stream (ISO-100, *Waste Management Technical Manual*). For comparison, the waste stream generated from the dissolution of the aluminum cladding from the irradiated fuel rods carried about 0.003 Ci/gal of ^{137}Cs (LA-UR-96-3860, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4*). Thus, a 1,000 gal loss of cladding waste would release approximately 3 Ci of ^{137}Cs, whereas a 1,000 gal loss of a typical PUREX HLW could release as much as 3×10^4 Ci of ^{137}Cs. The release of other soluble radionuclides present in the tank waste are assumed to be proportional to the ^{137}Cs measured. Thus, the waste type is important to estimating leak inventories.

Figure 2-1. Example of ^{137}Cs Activity for a Tank Leak in SX Tank Farm.



2.4 REVISED TANK/ANCILLARY EQUIPMENT LEAK VOLUME ESTIMATES

The tank/ancillary equipment leak volumes were updated based on investigation and review of past tank data. Table 2-2 shows a comparison of the SST leak volumes reported in HNF-EP-0182 as of March 31, 2005 and revised leak volumes for risk assessments. Future revisions of HNF-EP-0182 will be updated consistent with the estimates in this report. The volumes in this report represent a "best estimate" of the amount of contaminated waste in the vadose zone. They do not include water losses or residual waste in the tank ancillary equipment or piping within a tank farm. However, some volume estimates may include losses from overfills, transfer line leaks, or cascade line leaks and are not necessarily attributed to a tank leak.

As previously noted, the quality of tank/ancillary equipment leak estimates varies significantly. Some leaks are large with high-activity levels and have a strong documented technical basis. Others are "assumed" or "questionable" and little or no data is available to estimate a leak inventory or date. Tank/ancillary equipment leak estimates within the SST farms have been grouped into four categories defined in Section 1.2.

Table 2-2 identifies leak volume estimates for 68 SSTs and shows the following comparisons with previous estimates reported in HNF-EP-0182:

- 33 leak volume estimates were unchanged
- 7 leak volume estimates increased
- 9 leak volume estimates decreased (includes three BY farm tanks)
- 1 new estimate was added
- 18 tanks had no technical basis for a leak volume estimate and were assumed negligible.

The technical basis for leak volume estimates for each of the tanks/ancillary equipment and/or tank groupings is presented in Section 3.0.

The "waste composition year" shown in Table 2-2 is the year SIM uses as the HDW model waste composition for a tank at the time of a leak. In general, the "waste composition year" is just after the last waste transfer into a tank prior to an estimated leak date or when the Waste Status Transfer Records indicate an unexplained liquid level decrease. When in doubt, a year was selected in which a tank had a conservatively high waste composition (ie. high radioactivity). The years are not when the tank was declared a leaker (as shown in HNF-EP-0182) and not necessarily when a leak was assumed to occur (see Section 3).

Table 2-2. Former and Revised Tank Leak Volume Estimates (4 sheets)

Tank/Ancillary Equipment	UPR	HNF-EP-0182 (March 2005) leak volume (gal)	Revised leak volume (gal)	Waste Composition Year[4]	Group[2]
A-103	NA	5,500	5,500	1987	2
A-104	UPR-200-E-125	500 to 2,500	2,000	1975	2
A-105	UPR-200-E-126	10,000 to 277,000	1,000	1965	3
AX-102	NA	3,000	3,000	1975	2
AX-104	NA	---- [1]	No basis for estimate		4
B-101	NA	---- [1]	No basis for estimate		4
B-103	NA	---- [1]	No basis for estimate		4
B-105	NA	---- [1]	No basis for estimate		4
B-107	UPR-200-E-127	8,000	14,000	1965	1
B-110	UPR-200-E-128	10,000	10,000	1969	2
B-111	NA	---- [1]	No basis for estimate		4
B-112	NA	2,000	2,000		2
B-201	UPR-200-E-129	1,200	1,200	1965	2
B-203	UPR-200-E-130	300	300	1965	2
B-204	NA	400	400	1965	2
BX-101	UPR-200-E-131	---- [1]	4,000	1972	1
BX-102	UPR-200-E-132 UPR-200-E-5	70,000	91,600	1951	1
BX-108	UPR-200-E-133	2,500	2,500	1972	2
BX-110	NA	---- [1]	No basis for estimate		4
BX-111	NA	---- [1]	No basis for estimate		4
BY-103	UPR-200-E-134	<5,000	See [3]	1973	3
BY-105	NA	---- [1]	No basis for estimate		4
BY-106	NA	---- [1]	No basis for estimate		4
BY-107	NA	15,100	See [3]		3
BY-108	UPR-200-E-135	<5,000	See [3]	1974	3
C-101	UPR-200-E-136	20,000	1,000	1968	3

Table 2-2. Former and Revised Tank Leak Volume Estimates (4 sheets)

Tank/Ancillary Equipment	UPR	HNF-EP-0182 (March 2005) leak volume (gal)	Revised leak volume (gal)	Waste Composition Year[4]	Group[2]
C-105	UPR-200-E-16	Not Listed	1,000	1972	1
C-110	NA	2,000	2,000	1969	2
C-111	NA	5,500	5,500	1968	2
C-201	NA	550	550	1965	2
C-202	NA	450	450	1965	2
C-203	UPR-200-E-137	400	400	1957	2
C-204	NA	350	350	1957	2
S-104	NA	24,000	24,000	1965	1
SX-104	NA	6,000	6,000	1988	2
SX-107	UPR-200-W-140	<5,000	15,000	1963	1
SX-108	UPR-200-W-141	2,400 – 35,000	35,000	1966	1
SX-109	UPR-200-W-142	<10,000	2,000	1966	1
SX-110	NA	5,500	1,000	1976	3
SX-111	UPR-200-W-143	500	500	1974	2
SX-112	UPR-200-W-144	30,000	1,000	1968	3
SX-113	UPR-200-W-145	15,000	15,000	1958	1
SX-114	NA	----[1]	No basis for estimate		4
SX-115	UPR-200-W-146	50,000	50,000	1965	1
T-101	NA	7,500	10,000	1969	1
T-103	UPR-200-W-147	<1,000	3,000	1973	1
T-106	UPR-200-W-148	115,000	115,000	1973	1
T-107	NA	----[1]	No basis for estimate		4
T-108	NA	<1,000	1,000	1974	2
T-109	NA	<1,000	1,000	1974	2
T-111	NA	<1,000	1,000	1971	2
TX-105	NA	----[1]	No basis for estimate		4
TX-107	UPR-200-W-149	2,500	8,000	1977	1
TX-110	NA	----[1]	No basis for estimate		4
TX-113	NA	----[1]	No basis for estimate		4
TX-114	NA	----[1]	No basis for estimate		4

Table 2-2. Former and Revised Tank Leak Volume Estimates (4 sheets)

Tank/Ancillary Equipment	UPR	HNF-EP-0182 (March 2005) leak volume (gal)	Revised leak volume (gal)	Waste Composition Year[4]	Group[2]
TX-115	NA	----[1]	No basis for estimate		4
TX-116	NA	----[1]	No basis for estimate		4
TX-117	NA	----[1]	No basis for estimate		4
TY-101	NA	<1,000	1,000	1973	2
TY-103	UPR-200-W-150	3,000	3,000	1971	1
TY-104	UPR-200-W-151	1,400	1,400	1981	2
TY-105	UPR-200-W-152	35,000	35,000	1957	1
TY-106	UPR-200-W-153	20,000	20,000	1959	1
U-101	UPR-200-W-154	30,000	5,000	1959	3
U-104	UPR-200-W-155	55,000	55,000	1956	1
U-110	UPR-200-W-156	5,000 – 8,100	6,500	1975	1
U-112	UPR-200-W-157	8,500	8,500	1967	1

Notes:

[1] The leak volume estimates in HNF-EP-0182 for these tanks were based on an assumption that their cumulative leakage is approximately the same as for 18 of the 24 tanks where leak volumes were determined by liquid-level decreases. SSTs SX-110 and T-106 were considered atypical and were not included. SSTs B-201, -203, -204, and C-203, also excluded, are small 200-series diameter tanks. The 18 tank leak estimates that were included in the estimate were SSTs A-103, AX-102, B-107, B-110, BY-107, C-101, C-111, S-104, SX-104, SX-109, T-103, T-108, T-109, T-111, TY-101, TY-104, U-110, and U-112 (8901832B). The total liquid-loss assumed for the 19 tanks was 150,000 gal, an average of approximately 8,000 gal/tank.

[2] Tank leak estimates were placed in 1 of 4 groups for uncertainty estimates to be defined and used in SIM:
Group 1 - Well known and documented.
Group 2 - Small leaks, no change in leak volume estimates.
Group 3 - No evidence of higher leak volume in vadose zone.
Group 4 - No basis for leak volume estimate.

[3] Tank leak estimates for BY tank farm are combined in a total tank farm vadose estimate of 1,160 Ci of ^{137}Cs. The estimate is based on 1996 measurements. Volume estimates will be derived using the SIM and distributed between SSTs BY-103, BY-107, and BY-108.

[4] Year used in SIM to estimate tank waste composition when a leak started.
There is considerable uncertainty regarding the leak date for many of the single-shell tank leaks listed. In general, the leak dates for larger waste loss events are reasonably well known. However, for the smaller waste loss events (i.e., <3,000 gallons) many of the leak dates are highly uncertain. The leak dates for tanks SX-111, T-108 and TY-104 are leak confirmation dates identified in EP-0182 and differ from those used in SIM as of July 2005. The basis for dates used for these three tanks will be discussed in RPP-26744 (Soil Inventory Model Report [in draft]).

8901832B, 1989, "Single-Shell Tank Leak Volumes", Rev. 1, letter from R. J. Buamhardt to G. E. Gerton, U.S. Department of Energy, Richland Operations Office, dated May 17, Westinghouse Hanford Company, Richland,

Table 2-2. Former and Revised Tank Leak Volume Estimates (4 sheets)

Tank/Ancillary Equipment	UPR	HNF-EP-0182 (March 2005) leak volume (gal)	Revised leak volume (gal)	Waste Composition Year[4]	Group[2]

Washington.
HNF-EP-0182, 2004, *Waste Tank Summary Report for Month Ending March 31, 2005*, Rev. 204, CH2M HILL Hanford
Group, Inc., Richland, Washington.
NA = not applicable.
SIM = Soil Inventory Model.
UPR = unplanned release.

3.0 TANK-BY-TANK DISCUSSION OF LEAK VOLUME ESTIMATES

This section summarizes the technical basis for leak volume inventory estimates for 68 SSTs (see Table 2-2). These leak estimates may include losses from ancillary equipment and spills or overflows from the tank.

3.1 GROUP 1 TANKS

There are 20 tanks listed in Group 1. Leak volumes and inventories are well documented and consistent with tank records, geophysical records, and other sources of information. Excluding SST SX-109, tank leak estimates assigned to this group remained the same or increased as a result of new information. Although the leak volume estimate for SST SX-109 was changed from < 10,000 gal to 2,000 gal, the cumulative leak volume estimate for SSTs SX-107, SX-108, and SX-109 increased. The following sections provide a discussion of the basis for leak estimates for each of the tanks in this group.

3.1.1 Single-Shell Tank 241-B-107

An increased leak volume of 14,000 gal was estimated for SST B-107. A leak loss of 14,000 gal was projected based on waste transfer records that show a decrease in the tank waste volume from 541,000 gal to 527,000 gal from January 1965 to June 1969 (RPP-17702, *Origin of Waste in Single-Shell Tank 241-B-107*, Appendix A; LA-UR-97-311, *Waste Status and Transaction Record Summary*). At the time the liquid-level decreases were reported, the tank contained 1C/CW sludge from the 221-B Bismuth Phosphate Plant and PUREX coating removal waste. Although no waste transfers were reported during this period, the waste volume measurements varied from a low value of 535,000 gal (January through June 1964) to a high value of 549,000 gal (January through June 1965). The previous leak volume estimate for this tank was 8,000 gal (HNF-EP-0182), apparently based on the lower (1964) liquid-level reading. The median value assumed for this study was based on the high electrode reading for July through December 1964 of 541 kgal.

The spectral gamma logging data show gamma activity levels of 1,000 pCi/g of ^{137}Cs at the level of the tank base in drywell 20-07-02. The activity also includes ^{60}Co, ^{154}Eu, and ^{152}Eu. Two drywells on the other side of the tank (20-07-08 and 20-10-02) have near-surface ^{137}Cs contamination (< 10 pCi/g) and apparent deep (70 to 85 ft below ground surface [bgs]) ^{90}Sr contamination (GJ-HAN-128, *Tank Summary Data Report for Tank B-107*).

3.1.2 Single-Shell Tank 241-BX-101

The leak volume estimate for SST BX-101 was changed to 4,000 gal. Although no previous leak volume was reported for this tank, the spectral gamma logging data clearly indicates a plume emanating from the tank dome. Although the presence of a leak is well documented, the quantity of waste lost to the soil column is highly certain. SST BX-101 was classified as an assumed leaker in 1972 based on unexplained drywell activity observed near the tank (HNF-4872, *Single-Shell Tank Leak History Compilation*). The leak history for SST BX-101 indicates that a leak originated from a pump pit on the dome of the tank (RPP-10098). However, approximately 25 Mgal of high-activity waste moved through this tank from 1968 until the end of 1972 andthere may have been an active leak from the SST BX-101 pump pit over this 4-year period (GJ-HAN-95, *Tank Summary Report for Tank BX-101*). Two drywells (21-01-01 and 21-01-02) near SST BX-101 exhibit significant contamination (GJO-HAN-19, *Hanford Tank Farms Vadose Zone: BX Tank Farm Report*). The leak volume estimate for SST BX-101 of 4,000 gal is highly speculative and based on apparent unexplained liquid level decrease in the waste transfer records over this time period (RPP-7389).

Additional vadose zone characterization activities are scheduled in the region around tank BX-101 to help resolve the uncertainties about the volume of waste associated with the pump-pit leak.

3.1.3 Single-Shell Tank 241-BX-102

The leak volume estimate for SST BX-102 was increased from 70,000 to 91,600 gal. The previous estimate of 70,000 gal was based on a 1972 analysis of neutron logging data and gamma activity and assumed that high gamma activity was primarily from ^{137}Cs (ARH-2035, *Investigation and Evaluation of 102-BX Tank Leak*). The increased volume estimate is a result of evidence that became publicly available in the mid-1990s showing that SST BX-102 was overfilled in 1951 and this overfill event resulted in the loss of an estimated 91,600 gal of metal waste to the soil (HW-20438, pg 51, *Hanford Works Monthly Report for February 1951* and HW-20742, *Loss of Depleted Metal Waste Supernatant to Soil*). Spectral gamma logging data obtained since the 1972 analysis show a ^{238}U plume from the tank overfill event and a complex array of gamma emitting radionuclides (RPP-10098). Gamma analyses show that little ^{137}Cs was in the high gamma activity region reported in ARH-2035, rather the contamination was a combination of ^{106}Ru, ^{60}Co, and ^{125}Sb.

3.1.4 Single-Shell Tank 241-C-105

A 1,000 gal leak is estimated for SST C-105 ancillary equipment. No previous leak volume is identified in HNF-EP-0182 for this tank. SST C-105 is not classified as an assumed leaker (HNF-EP-0182) because documentation on SSTs C-104 and C-105 refer to a tank leak in the cascade line between the two tanks. Gamma-ray log data from boreholes in the region between these two tanks also suggest a cascade line leak (RPP-20820). The cascade line leak is listed as UPR-200-E-16. However, no documentation was found showing when the leak occurred, how it was first found, and how it was determined to be a cascade line leak (WHC-SD-EN-TI-185, *Assessment of Unsaturated Zone Radionuclide Contamination Around Single-Shell Tanks 241-C-105 and 241-C-106*, p.16).

The estimate is based on high levels of ^{137}Cs activity (> 10^7 pCi/g) measured between 1974 and 1979 near the tank base in drywell 30-05-07 and near the cascade line inlet. Comparatively low contamination levels were measured in surrounding drywells (RPP-20820). The next highest level was about 10^3 pCi/g found at 13 ft bgs in drywell C4297. Drywell C4297 was drilled in 2004 in an attempt to better characterize the C-105 plume, which is located approximately 9 ft from SST C-105 and near drywell 30-05-07.

The data are inconclusive as to the source of the cesium plume observed in drywell 30-05-07 due to the lack of evidence linking the cascade leaks to the drywell activity. Regardless of the source of the contamination, a contaminant plume clearly exists. Based on the plume size estimated from ^{137}Cs distribution and concentration measurements in drywell 30-05-07 and comparatively low ^{137}Cs activity levels in surrounding drywells, the leak volume was estimated to be < 1,000 gal. A larger plume would be expected to show substantially higher activity levels in one or more of the surrounding drywells.

3.1.5 Single-Shell Tank 241-S-104

The leak volume for SST S-104 was unchanged at 24,000 gal. SST S-104 is estimated to have lost 24,000 gal, probably through a spare inlet port, based on unexplained liquid-level decreases from 1966 through 1970 (RPP-6285, HNF-EP-0182). SST S-104 was declared a confirmed leaker in 1968. Based on soil contamination levels and waste transfer records, the fluids lost were likely aluminum cladding waste. A 24,000 gal loss of reduction and oxidation (REDOX) cladding waste would involve the loss of approximately 550 Ci of ^{137}Cs. This level of ^{137}Cs contamination is consistent with the ^{137}Cs activity found in one nearby drywell, near the spare inlet ports, and found in cone penetrometer pushes around this drywell (GJ-HAN-73, *Tank Summary Data Report for Tank S-104*; RPP-7884).

3.1.6 Single-Shell Tank 241-SX-107

The estimated leak volume for SST SX-107 was increased from < 5,000 to 15,000 gal. This tank was classified as a confirmed leaker in 1964 based on drywell activity. The revised leak volume was scaled to a 35,000 gal leak from SST SX-108 based on ^{137}Cs kriging analysis (RPP-20420, *241-S-SX Waste Management Area Inventory Data Package*). The kriging analysis is essentially a means of ratioing cesium distribution between the tanks. The original kriging analysis (HNF-5782, *Estimation of SX-Farm Vadose Zone Cs-137 Inventories from Geostatistical Analysis of Drywell and Soil Core Data*) estimated a 6,350 gal leak volume for SX-107 based on a 15,200 gal leak for SST SX-108. This is close to the previous leak volume estimate of < 5,000 gal (HNF-EP-0182). However, given the poorly defined uncertainty for the kriging analysis, the ratio of the leak volumes derived from the kriging analysis for SSTs SX-107, SX-108, and SX-109 (6,350 gal, 15,200 gal, and 989 gal, respectively) was applied to an upper 35,000 gal leak estimate for SST SX-108 resulting in a 15,000 gal estimate for SST SX-107.

3.1.7 Single-Shell Tank 241-SX-108

The best leak volume estimate for SST SX-108 was determined to be the maximum value presented in HNF-EP-0182 of 35,000 gal. SST SX-108 is a confirmed leaker based on drywell activity. Previous leak estimates range from 2,400 to 35,000 gal (HNF-EP-0182) based on a 1992 leak assessment (WHC-MR-0300, *Tank 241-SX-108 Leak Assessment*). The first leak was noted in 1964 during sodium-nitrate recovery operation (BNWL-CC-701, *Characterization of Subsurface Contamination in the SX Tank Farm*; WHC-MR-0300) and quantified as a 24,000 gal leak based on soil sample analyses (WHC-MR-0300). A second major leak from this tank was believed to have begun in 1966 when the tank was filled with REDOX HLW. Extensive historical documentation is available for the tank leak, and extensive field investigations were performed assessing this leak including lateral, drywell, and in-tank investigations. As part of the WMA S-SX field investigation report (RPP-7884), a leak volume of 15,200 gal was developed for SST SX-108 based on geo-statistical (kriging) analysis of spectral gamma logging and soil analysis data (HNF-5782). Given poorly defined uncertainty for the kriging analysis results and a possibility that results may be low by as much as a factor of two, the upper 35,000 gal leak volume was assumed for S-SX risk assessments (RPP-20420). Kriging analyses for SSTs SX-109 and SX-107 were increased proportionally.

3.1.8 Single-Shell Tank 241-SX-109

The estimated leak volume for SST SX-109 was changed from < 10,000 gal to 2,000 gal. SST SX-109 was classified as a confirmed leaker based on drywell activity (HNF-EP-0182). As noted in Section 3.1.7, leak volumes for SST SX-109 were scaled to the leak from SST SX-108 based on ^{137}Cs kriging analysis (HNF-5782). Originally, the leak volume estimate for SST SX-109 was determined to be "small" (ARH-R-43, *Management of Radioactive Waste Stored in Underground Tanks at Hanford*; BNWL-CC-701). An estimate of < 5,000 gal was given in 1983 (PNL-4688 UC-70, *Assessment of Single-Shell Tank Liquid Residual Issues at Hanford Site, Washington*), but this estimate was never substantiated. In 1992, the leak volume was estimated as < 10,000 gal (WHC-MR-0301, *Tank 241-SX-109 Leak Assessment*) based on lateral activity measurements and engineering judgment. Subsequent, kriging analysis indicated that more of the waste was derived from SST SX-107 and less from SST SX-109 as originally suspected (ARH-R-43). The SST SX-109 contained REDOX sludge and supernatant boiling waste at the time of the suspected tank leak.

3.1.9 Single-Shell Tank 241-SX-113

The estimated leak volume for SST SX-113 remains unchanged at 15,000 gal. The tank is classified as a confirmed leaker based on a liquid-level decrease during a tank leak test (HW-75714, *Leak Testing of the 113-SX Tank*). The base of SST SX-113 bulged during the initial filling with REDOX HLW. The tank was pumped to a minimum heel, drywells were installed, and five laterals were placed under the tank for gross gamma logging (RPP-20420). Over a 2-year period, no activity was detected in the laterals or drywells. In 1962, 208,000 gal of dissolved sludge waste was transferred from SST SX-114 to SST SX-113 as a tank-leak test.

A leak volume of 15,000 gal was measured during the leak test (HW-75714). The tank was pumped to a minimum heel and taken out of service.

3.1.10 Single-Shell Tank 241-SX-115

The estimated leak volume for SST SX-115 remains unchanged at 50,000 gal. The 50,000 gal loss from SST SX-115 is well documented (BNWL-CC-701). Extensive historical documentation is available for the tank leak (WHC-MR-0302, *Tank 241-SX-115 Leak Assessment*). Waste transfer records and waste types also indicate a 50,000 gal loss for the SST SX-115 leak event (RPP-6285).

3.1.11 Single-Shell Tank 241-T-101

The estimated leak volume for SST T-101 was increased from 7,500 gal to 10,000 gal based on tank transfer and surveillance records. SST T-101 was classified as an assumed leaker in 1992 with a leak volume of 7,500 gal based on a liquid-level decrease (HNF-EP-0182). This tank was overfilled in the 1960s and is reported to have lost an unknown quantity of REDOX cladding waste through a defective spare inlet port in 1969 (GJ-HAN-115, *Tank Summary Data Report for Tank T-101*). The location (drywell 50-01-04) and the ^{137}Cs profile found during spectral gamma logging are consistent with waste loss through a spare inlet port. Contamination profiles in drywells 50-01-06 and 50-01-09 suggest near-surface leaks of REDOX ion-exchange waste stored in this tank in the early 1970s. Based on analysis of waste transfer records, the leak volume associated with the tank overfill event was increased to 10,000 gal and the waste composition is based on a leak in that time frame (RPP-7218). Additional field characterization is planned near this tank.

3.1.12 Single-Shell Tank 241-T-103

The estimated leak volume for SST T-103 was increased from < 1,000 gal to 3,000 gal based on tank transfer and surveillance records. A leak volume of < 1,000 gal is listed for this tank with a declared leak date of 1974 (HNF-EP-0182). The contamination around SST T-103 has been suggested to have originated from a waste loss through a spare inlet port when the tank was overfilled in 1972 and 1973 (GJ-HAN-117, *Tank Summary Data Report for Tank T-103*). The radionuclide profiles suggest a B Plant origin for the lost tank waste. Analysis of tank transfer records suggests a 3,000 gal leak volume, which will be used for risk assessments. A detailed description and leak evaluation of SST T-103 is contained in RPP-20820 and *Subsurface Conditions Description of the T and TX-TY Waste Management Areas* (RPP-7123).

3.1.13 Single-Shell Tank 241-T-106

The estimated leak volume for SST T-106 remains the same at 115,000 gal. The 115,000 gal leak from SST T-106 in 1973 was the largest waste-loss event recorded at the Hanford Site. It is well documented in *High-Level Waste Leakage from the 241-T-106 Tank at Hanford* (RHO-ST-14). Data are available from analyses of waste performed at the time of the leak. Additional field characterizations are planned near this tank. Additional information about the tank and leak is presented in RPP-7123 and *Hanford Tank Farms Vadose Zone: T Tank Farm Report* (GJO-HAN-27).

3.1.14 Single-Shell Tank 241-TX-107

The leak volume estimate for SST TX-107 was increased from 2,500 gal to 8,000 gal. A leak volume of 2,500 gal for this tank and a declared leak date of 1984 (HNF-EP-0182) was based on increasing activity in nearby drywells (Occurrence Reports 77-103 and 83-22). The zones at 50 to 70 ft bgs in drywells 51-07-18 and 51-07-07 are contaminated with ^{60}Co and ^{154}Eu, as are other drywells between SSTs TX-103 and TX-107. SST TX-107 was used as the 242-T Evaporator feed/bottoms recycle tank in 1975, apparently handling B Plant ^{90}Sr recovery waste. The gamma plumes (i.e., ^{60}Co and ^{54}Eu) around this tank indicate a substantial leak volume. The leak volume was increased to 8,000 gal based on plume size estimates. The actual value is uncertain (RPP-7218). Additional description of the tank and leak information is presented in RPP-7123 and *Hanford Tank Farms Vadose Zone, TX Tank Farm Report* (GJO-HAN-11). Results from a field characterization program are presented in *A History of the 200 Area Tank Farms* (WHC-MR-0132).

3.1.15 Single-Shell Tank 241-TY-103

The previous leak estimate for SST TY-103 of 3,000 gal is not changed. A leak volume of 3,000 gal and a declared leak date of 1973 were assigned based on an unexplained liquid-level decrease (HNF-EP-0182). Spectral gamma logging data from drywell 53-03-03 indicates ^{137}Cs contamination near the base of this tank that could have originated from a tank leak or from waste transfer lines. Drywells 53-03-06 and 53-03-12 have deep ^{60}Co contamination (GJO-HAN-16, *Hanford Tank Farms Vadose Zone: TY Tank Farm Report*). The combination of ^{137}Cs and ^{60}Co suggests TBP or B Plant waste source (RPP-7218). This tank stored TBP waste from 1957 through early 1968. From 1968 through 1973, SST TY-103 contained PUREX and B Plant waste. Additional information about the tank and leak is presented in RPP-7123 and GJO-HAN-16.

3.1.16 Single-Shell Tank 241-TY-105

The previous leak estimate for SST TY-103 of 35,000 gal is not changed. A leak volume of 35,000 gal and a leak date of 1960 were assigned based on drywell activity and waste transfer records which show an unaccounted-for 35,000-gal liquid-level decrease of TBP waste in 1959. The limited number of drywells around this tank indicates gamma contamination that is consistent with loss of TBP waste (GJO-HAN-16). Both ^{137}Cs and ^{60}Co were found in drywells 52-03-06, 52-05-07, and 52-06-05. TBP waste was the only waste type added to this tank (RPP-7218). Additional information about the tank and leak is presented in RPP-7123.

3.1.17 Single-Shell Tank 241-TY-106

The previous leak estimate for SST TY-106 of 20,000 gal is not changed. A leak volume of 20,000 gal and a leak date of 1959 were assigned based on increased drywell activity in four of five nearby wells (HNF-EP-0182). In February 1972, diatomaceous earth was added to the tank in an attempt to stabilize it. SST TY-106 received waste from SST TY-105 through the cascade line. Thus, both tanks contained TBP waste. Although the waste transfer records indicate an apparent waste loss in 1959, the data are ambiguous (RPP-7218). Additional information about the tank and leak is presented in RPP-7123 and GJO-HAN-16.

3.1.18 Single-Shell Tank 241-U-104

The previous leak estimate for SST U-104 of 55,000 gal (HNF-EP-0182) is not changed. A 55,000 gal leak from SST U-104 occurred in the early 1950s when physical inspection of the tank interior (GJ-HAN-33, *Tank Summary Data Report for Tank U-104*) revealed a tank bottom bulge in the northeast quadrant of the tank. Spectral gamma-uranium activity data in 10 drywells around SST U-104 and to the southwest indicate the occurrence of a high-uranium waste leak with SST U-104 being the source. Maximum uranium concentrations over the largest depth intervals occur in drywells 60-07-11, 60-07-10, and 60-04-08 on the south and southwest side of SST U-104. In these drywells, contamination occurs just below the tank bottom about 52 ft (16 m) bgs and extends to as much as 92 ft (28 m) bgs. Uranium-235 concentrations up to 100 pCi/g and ^{238}U concentrations approaching 1,000 pCi/g near tank bottom depth have been measured. These drywells were located closest to the leak location. Given the extent of the uranium contamination footprint in the vadose zone, the leak volume estimate may be larger than 55,000 gal. However, pending additional characterization/analysis, the leak estimate was not changed. Additional information about the tank and leak is presented in RPP-15808.

3.1.19 Single-Shell Tank 241-U-110

The previous leak estimate for SST U-110 of 5,000 gal to 8,100 gal (HNF-EP-0182) was not changed. However, a single value of 6,500 gal was selected. An SST U-110 leak was reported in 1975 based on increased gamma activity in drywell 60-10-07 and a liquid-level decrease inside the tank (SD-WM-TI-356, *Waste Storage Tank Status and Leak Detection Criteria*). The tank leak volume is estimated to range between 5,000 and 8,100 gal (HNF-EP-0182; SD-WM-SAR-006, *Single-Shell Tank Isolation Safety Analysis Report*). Both spectral gamma data and the historical gross gamma record are consistent with a tank leak. An average leak volume of 6,500 gal was assumed (RPP-16608, *Site-Specific Single-Shell Tank Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan Addendum for Waste Management Areas C, A-AX, and U*). Additional information about the tank and leak is presented in RPP-15808 and *Vadose Zone Characterization Project at the Hanford Tank Farms, U Tank Farm Report* (GJO-HAN-8).

3.1.20 Single-Shell Tank 241-U-112

The previous leak estimate for SST U-112 of 8,500 gal (HNF-EP-0182) was not changed. SST U-112 was classified as a confirmed leaker in 1970 with leak volume of 8,500 gal based on a liquid-level decrease (HNF-EP-0182). A review of historical leak information provided in RPP-20820, Section 4.9, indicates the leak volume may have been larger. SST U-112 appears to have leaked in a similar fashion to SST U-110. One drywell, 60-02-01, shows two distinct high ^{137}Cs concentration zones near the tank bottom between 50 and 68 ft (15 and 21 m) bgs. Concentrations exceeding 10^7 pCi/g are common and a maximum value near 10^9 pCi/g occurs near 60 ft (18 m) bgs. A second less concentrated zone occurs between 83 and 97 ft (25 and 30 m) bgs where ^{137}Cs concentrations largely fall between 10^4 and 10^5 pCi/g. The bifurcated zones could indicate more than one leak (RPP-15808). However, pending additional characterization/analysis, the previous leak estimate was not changed.

3.2 GROUP 2 TANKS

There are 22 tanks listed in Group 2. The leak volumes shown in HNF-EP-0182 for these tanks were not changed. In general, the leak volumes reported for these tanks are smaller than leak volumes that normally would be detected by vadose zone drywell measurements (Appendix A). In some cases, the "leak" appears to have originated near surface. The logic leading to the leak volume estimates for these tanks vary in both level of sophistication and reproducibility. Leak volume estimates in this category generally are too small to be supported by vadose estimates or technical arguments and appear to be conservative. However, information available at the time - but not recorded in a retrievable archive; loss of key personnel over the years; and the small size of many of the leaks make any current formal re-evaluation likely to yield questionable results. Because new field data does not add new information to validate or change these estimates, the leak volume estimates shown in HNF-EP-0182 for these 22 tanks were not changed. Inventory estimates in SIM will be developed based on the concentration of liquid waste types in a tank at the time the liquid-level decrease occurred.

The 22 tanks in Group 2 are: SSTs A-103, A-104, AX-102, B-110, B-112, B-201, B-202, B-204, BX-108, C-110, C-111, C-201, C-202, C-203, C-204, SX-104, SX-111, T-108, T-109, T-111, TY-101, and TY-104.

No further description or discussion of these tank/ancillary equipment leak volume estimates is included in this document. Leak volume estimates for these tanks are shown in Table 2-2.

3.3 GROUP 3 TANKS

Group 3 includes eight SSTs on the "confirmed or suspected" leaker list for which current vadose zone drywell and/or lateral measurements and investigations indicate that previous leak volume estimates were high. The leak volume estimates for five tanks in this group were reduced. These tanks include SSTs A-105, C-101, SX-110, SX-112, and U-101. Previous leak volume estimates for these tanks were 10 kgal, 20 kgal, 5.5 kgal, 30 kgal, and 30 kgal, respectively (HNF-EP-0182), and involve REDOX or PUREX HLW. Given the high-heat load of these waste types and understanding of fluid-flow in the Hanford Site's unsaturated soils, it is highly unlikely that a leak volume of these magnitudes would not have been detected by the secondary leak monitoring (i.e., the drywell gross gamma logging) system.

The leak volumes for SSTs BY-103, BY-107, and BY-108 will also be reduced. Vadose zone drywell logging shows extensive surface contamination near these tanks. Much of the liquid-level decreases may be accounted for by evaporation and intermixing makes it difficult to determine the contamination source. A cumulative estimate of contamination observed in drywells near these three tanks and the size of contamination plumes was performed and is described in Section 3.3.2. An estimate of approximately 1,160 Ci of ^{137}Cs in the BY tank farm vadose zone was developed for these tanks. The ^{137}Cs inventory assigned to each of the BY tank farm tanks/ancillary equipment was proportional to the leak volumes presented in HNF-EP-0182, (5,000 gal for BY-103, 15,100 gal for BY-107 and 5,000 gal for BY-108) resulting in 0.2 * 1,160 or 232 Ci for SSTs BY-103 and BY-108 and 928 Ci for SST BY-107. Total inventories and leak volume estimates will be developed in the SIM based on a knowledge of waste types in these tanks at the times of waste-loss events.

A more detailed discussion of each of the tanks in this group, the basis for reducing leak volume estimates, and calculations and assumptions for BY-tank Ci estimates follows.

3.3.1 Single-Shell Tank 241-A-105

The estimated leak volume for SST A-105 was decreased from a range of 10,000 to 277,000 gal to a nominal 1,000 gal. This is by far the biggest change presented in this report and one of the most controversial.

The previous leak volume estimate for this event is 10,000 to 277,000 gal, including 10,000 to 45,000 gal of waste prior to November 1970 and 0 to 232,000 gal of cooling water (HNF-EP-0182). An estimated 610,000 gal of cooling water was added to the tank between November 1970 and 1978 with a minimum evaporation estimate of 378,000 gal (WHC-MR-0264, *Tank 241-A-105 Leak Assessment*). A net maximum volume of 232,000 gal of cooling water assumed to have leaked to the vadose zone; however, "sufficient heat was generated in the tank to evaporate most, and perhaps nearly all, of the water" (WHC-MR-0264) to provide a minimum value of 0. Cooling water additions were not included in the nominal 1,000 gal estimate because the water does not contribute to the volume or inventory of waste leaked to the vadose zone. The quantity of cooling water leaked to the vadose zone is assumed to range between 0 and 232,000 gal (WHC-MR-0264).

Subtracting cooling water additions leaves 10,000 to 45,000 gal of liquid waste to account for. The spectral gamma logging data are inconsistent with a 10,000 gal loss of PUREX HLW from SST A-105 to the soil. Analytical data show that the ^{137}Cs concentration in SST A-105 supernatant at the time of the steam release event was 8.1 Ci/L (31 Ci/gal) (ARH-78, *PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and*

Control). Thus, a 10,000-gal leak volume would require that 310,000 Ci of ^{137}Cs were lost to the soil column. However, the drywells around SST A-105 have very low levels of ^{137}Cs contamination (< 100 pCi/g).

In 1963, the first recorded leak from SST A-105 was reported (ARH-78). The estimate for this leak was 5,000 to 15,000 gal based on drywell measurements available at the time (WHC-MR-0264). The dry lateral [10-05-Lateral 3] posted a radiation contamination level of 17,000 cpm gamma. Seven days later that measurement jumped to 150,000 cpm gamma and 0.75 R/h. Over a 3-month period the contamination decreased to 50,000 cpm. A leak was the assumed cause for the sudden increase and eventual decrease in radioactive contamination. In comparison, inside the waste tank a radioactive contamination measurement was taken at 40,000 R/hr (millions of cpm). Tank farm condensate was added just before the assumed leak occurred. The radioactivity of the condensate added to the tank was measured at 200 cpm. After the condensate was added, the in-tank condensate was measured at 8,000 cpm. The leak was assumed to be small due to the minimal amount of radiation present in the lateral compared to the expected radioactivity for a larger leak from the tank (ARH-78). The tank was again filled to capacity by December 1964 with no indications of a leak.

The most serious waste-loss event from WMA A-AX occurred in SST A-105 in January 1965 (ARH-78). The tank was filled to capacity with PUREX HLW in a boiling state. The extreme high-heat load led to an intense steam release event that lasted for 30 minutes. This event also caused a bulge in the bottom inner liner upward to an estimated 8.5 ft at one point, ripped the liner away from the sidewall, and displaced approximately 80,000 gal of liquid (void volume estimate) within the tank. The tank was closely monitored for several years with no evidence of additional leakage. However, some liquid-level losses were noted during the final attempt to sluice the hard heel from the tank. Following the unsuccessful attempt to remove the hard heel, water was added to the tank for evaporative cooling for almost a decade.

Thirty-nine days after the "steam event," 10-05-Lateral 3 posted a radioactive contamination measurement of 3,000,000 cpm; it also read 50,000 cpm from the leak detected 2 years earlier. The thermal temperature measured in a second set of laterals installed just below the base of the tank was 310° F (90 ft horizontal from the caisson). Tank farm officials, fearing a leak from SST A-105, had three test wells drilled in the general area of 10-05-Lateral 3 to intercept and analyze the leaked substance. All three test wells were drilled and sampled to approximately 65 ft bgs. Analysis showed no signs of radioactive materials and maximum soil temperature for all three wells at 206° F (ARH-78). In 1998, the 10-05-Lateral 3 temperature was measured at 233° F. Although the lateral readings and temperature were high, they were still very low compared to in-tank measurements and activity levels expected for a PUREX HLW leak.

Information provided by Pacific Northwest National Laboratory (PNNL) in past reports (ARH-78; BNWL-CC-376, *Techniques for Calculating Tank Temperatures and Soil Temperatures Near Leaks – Application to PUREX Waste Tank 105A*) indicate if a minimal amount [~ 175 gal] of solution or supernatant liquid was transferred from SST A-105 to the soil, the resultant temperature could be in excess of +1500° F. A 1970 report (ARH-R-43) does not estimate a leak volume, but indicates the volume was "small" and assumes that the leak had self sealed and that periodic liquid fluctuations and a bulge under the liner were "attributed to movement of solution in and out of the space between the bulged liner and the concrete bottom through a break in the liner. The liquid was removed during the June 1968 period."

A 1977 study (Woodward-Clyde 1978, *An Estimate of Bottom Topography, Volume and other Conditions in Tank 105A, Hanford, Washington*) estimated that 21,000 gal of sludge was trapped between the bulged liner and the tank wall. This sludge waste is part of the in-tank best-basis inventory (BBI) estimate (*Tank Waste Information Network System* [TWINS] 2004) for tank residuals and is in addition to an estimated 16,000 gal of sludge "in the tank." The 21,000 gal is well above a 10,000-gal leak estimate.

This drywell and lateral data do not support a 10,000-gal leak estimate. A previous assessment (WHC-MR-0264) concluded that based on the PNNL study (ARH-78) and the fact that the temperature in the laterals never exceeded 350° F it appears likely that very little if any of the solid sludge materials escaped from the tank. The PNNL study provides the only available quantification for how much waste might have reached the soil as "less than 175 gal." This is not to say that the tank leak volume was not higher than 175 gal, but suggests that waste that leaked from the tank was likely diluted and the inventory of PUREX HLW that leaked from the tank appears to be lower than previously predicted. WHC-MR-0264 also concludes that the leaks were "small" because horizontal spreading was not observed and radiation readings detected are a small fraction of the radiation reading in the tank. The deminimus level for drywells (in the absence of laterals) presented in this report as a result of recent leak detection monitoring and liquid spreading studies is 5,000 gal (Appendix A). In addition, the activity level and temperatures were significantly lower than expected in laterals only 10 ft below the tank. Not only was there no evidence of activity in drywells in place at the time, but no activity was found in three new drywells that were drilled after the leak events occurred. These drywells were located near high activity measurements in the laterals in an effort to further characterize SST A-105 contamination and the plume size.

In light of the available information, a nominal volume of 1,000 gal of PUREX high-level supernatant in the vadose zone was assumed. Attempts to re-log the laterals under SST A-105 using a spectral gamma logging tool are part of the A tank farm vadose zone investigations. Such data will further quantify the ^{137}Cs plume in the soil directly below the tank. The results for SST A-105 will be revised after the new spectral gamma lateral data are obtained.

3.3.2 Single-Shell Tanks 241-BY-103, BY-107, and BY-108

An estimate of approximately 1,160 Ci of ^{137}Cs in the BY tank farm vadose zone was developed for SSTs BY-103, BY-107, and BY-108. Volumes and inventories for ^{137}Cs and other waste constituents will be developed in the SIM based on a knowledge of waste types in these tanks at the times of waste-loss events.

Tanks and surface-level contamination in BY tank farm are intermixed and make it difficult to distinguish which tanks leaked and how much. However, vadose data shows extensive ^{137}Cs surface (top 0 to 40 ft) contamination in BY tank farm attributed to tank leaks, pipeline losses, and spills. These pipeline leaks and spills are not accounted for in the UPRs shown in

Section 4.0. Therefore, in place of questionable and highly uncertain individual tank leak estimates and possible overlap or duplication, a single BY tank farm vadose zone inventory attributing to tanks and ancillary equipment for SSTs BY-103, BY-107, and BY-108 was developed from spectral gamma logging data.

SSTs BY-103, BY-107, and BY-108 are classified as assumed leakers based on low levels of unexplained activity in nearby drywells (HNF-EP-0182).

SST BY-103 was declared a leaker based on drywell activity with a leak volume of < 5,500 gal (HNF-EP-0182). Drywell monitoring data (drywell 22-03-09) shows ^{137}Cs activity near the surface indicating that the contamination may have come from a near-surface leak associated with a leak detected in early 1973 when the tank contained about 14 ft of wet salt. After removing approximately 44,000 gal of saltwell liquor, future ^{60}Co activity increases found near the tank base may be attributed to migration from the cesium activity source (OR-74-106, *Increasing Radioactivity in Dry Well 22-03-09 at Tank 103-BY*).

SST BY-107 is classified as a confirmed leaker based on an unexplained liquid-level decrease with a leak volume of 15,100 gal (HNF-EP-0182). A 1974 occurrence report (OR-74-27, *Significant Liquid Level Decrease – Tank 241-107-BY*) notes that the liquid level decreased beyond that expected due to surface crusting and exhauster operation. Radiation peak readings were observed in a drywell near the northeast quadrant of the tank. The tank was shut down in June 1973 and approximately 167,000 gal of liquid were removed from the tank during April 1974. The surface level appeared to stabilize after pumping; however, accelerated removal of liquids continued as a precaution. The 1975 increases in drywell activity were probably caused by redistribution of contamination in the soil. Drywells on the east side of SST BY-107 show a high amount of moisture in the soil attributed to moisture intrusion from a nearby french drain and a raw water outlet between SSTs BY-104, BY-105, BY-107, and BY-108 (OR-75-56, *Increasing Dry Well Radiation Adjacent to Tank 107-BY*).

SST BY-108 is classified as a confirmed leaker with a leak volume of < 5,500 gal based on high radiation readings, frequent scintillation-probe checks, coupled with neutron-probe readings revealed an active leak near the bottom and northerly quadrant of the tank in June 1971 (PPD-453, *Monthly Status and Progress Report*, June 1971 P. AIV-18). Pumping started January 1972.

The spectral gamma logging data provide evidence that waste-loss events in the BY tank farm originated from within 25 ft of the ground surface. The vadose zone of this tank farm is highly contaminated with ^{137}Cs near surface while deeper gamma activity comes from ^{60}Co.

Most BY tank farm drywells were installed in the early to mid-1970s. In the 1970s, high levels of gross gamma activity were observed near or below the base of a number of BY tank farm tanks. The high levels of gross gamma activity near or below the base of these tanks were interpreted as strong evidence for leaks from any nearby tank. However, the spectral gamma logging data (GJO-HAN-6, *Vadose Zone Characterization Project at the Hanford Tank Farms, BY Tank Farm Report*) provides a significantly different interpretation. In the year 2000, the activity near and below the base of the tanks in the BY tank farm was ^{60}Co. The historical gross gamma logging data were evaluated in *Analysis of Historical Gross Gamma Logging Data from BY Tank Farm* (HNF-3532) in 1999. Their analysis showed that many of the drywells had high levels of ^{60}Co, ^{106}Ru, and ^{125}Sb activity near and below the base of a number of tanks in the mid- and late-1970s. Almost all of the high ^{137}Cs activity was between 0 and 20 ft bgs. Based on our current understanding of ^{137}Cs migration in the Hanford subsurface, these data demonstrated that the waste-loss events in the BY tank farm originated in this region between 0 and 20 ft bgs.

Leak volumes that are reported for BY tank farm are questionable. The leak volumes were reported more than 10 years ago after an initial concern about high gamma activity observed in drywells. These tanks were flagged as potential leakers. As a result, a total BY tank farm vadose zone ^{137}Cs inventory estimate was developed from spectral gamma logging data. Results from this approach are reported below. The total ^{137}Cs activity can be used to develop inventories for other chemicals and radionuclides.

The BY tank farm spectral gamma logging data (GJO-HAN-6) identify five regions of high ^{137}Cs gamma activity (i.e., at > 1E + 04 pCi/g). The decay date for these ^{137}Cs estimates is 1996 (the date data was collected). The regions are as follows:

1. Drywells 22-08-01 and 22-08-02 from 2 to 7 ft bgs at 1E + 05 pCi/g (assume a 50-ft diameter circular plume).

2. Drywell 22-05-01 from 0 to 3 ft bgs at 1E + 04 pCi/g (assume a 25 ft circle).

3. Drywell 22-12-03 from 5 to 7 ft bgs at 1E + 04 pCi/g (assume a 25 ft circle).

4. Drywell 22-03-05 from 27 to 45 ft bgs at 3E + 03 to 4E + 07 pCi/g (assume a 25 ft circle).

5. Finally, there is the generally contaminated region from 0 to 10 ft bgs all across the BY tank farm at < 1E + 02 pCi/g.

Assuming an average soil density of 1.8 g/cc, 1 ft^3 equals 2.832E + 04 cm^3, thus, 1 ft^3 would contain 5.1E + 04 g of soil. A 25 ft circle of cesium contamination with a 1 ft depth would contain 491 ft^3 or 2.5E + 07 g of soil. A 50 ft circle 1 ft thick would include 1,964 ft^3 or 5.561E + 07 cm^3 or 1.0E + 08 g of soil. A 5-ft thick plume would include 5.0E + 8 g of soil.

1. Drywells 22-08-01 and 22-08-02 from 2 to 7 ft bgs at 1E + 05 pCi/g (assume a 50-ft diameter circular plume). A ^{137}Cs activity of 1E + 05 pCi/g would lead to an estimate of 50 Ci of ^{137}Cs in this plume.

2. Drywell 22-05-01 from 0 to 3 ft bgs at 1E + 04 pCi/g (assume a 75 ft circle). This leads to an estimate of 0.25 Ci of ^{137}Cs in this plume.

3. Drywell 22-12-03 from 5 to 7 ft bgs at 1E + 04 pCi/g (assume a 25 ft circle). This leads to an estimate of 0.5 Ci of ^{137}Cs in this plume.

4. Because of the depth and activity variations in the plume associated with drywell 22-03-05, a "layer cake" model was used to develop the inventory estimate. The "layer cake" model for drywell 22-03-05 assumes a 25-ft diameter circle. According to the layer cake model:

   - From 27 to 32 ft bgs, ^{137}Cs activity = 2E + 04 pCi/g. This leads to an estimate of 2.5 Ci of ^{137}Cs.
   - From 32 to 34 ft bgs, ^{137}Cs activity = 1E + 06 pCi/g. This leads to an estimate of 50 Ci of ^{137}Cs.
   - From 34 to 35 ft bgs, ^{137}Cs activity = 4E + 07 pCi/g. This leads to an estimate of 1,000 Ci of ^{137}Cs.
   - From 35 to 37 ft bgs, ^{137}Cs activity = 1E + 06 pCi/g. This leads to an estimate of 50 Ci of ^{137}Cs.
   - From 37 to 45 ft bgs, ^{137}Cs activity = 1E + 04 pCi/g. This leads to an estimate of 2 Ci of ^{137}Cs.
   - The "layer cake" model estimate for the plume around drywell 22-03-05 leads to an estimate of approximately 1,100 Ci of ^{137}Cs.

5. Finally, there is the generally contaminated region from 0 to 10 ft bgs all across the BY tank farm at < 1E + 02 pCi/g. Assume the tank farm is 300 by 400 ft. The total volume is 1.2E + 06 ft^3. This leads to 6.12E + 10 g of soil. At a uniform activity of 100 pCi/g leads to an estimate of 6.1 Ci of ^{137}Cs.

This analysis leads to an estimate of approximately 1,160 Ci of ^{137}Cs in the BY tank farm vadose zone. Volumes and inventories for other waste constituents will be developed from a knowledge of waste types in these tanks at the times of waste-loss events using the SIM. For comparison, a BY tank farm vadose zone ^{137}Cs inventory estimate of approximately 30 Ci is provided in *Addendum to the BY Tank Farm Report* (GJO-HAN-6) September 2000. Thus, the current ^{137}Cs inventory estimate is considerably more conservative than that provided in the MACTEC-ERS report.

3.3.3 Single-Shell Tank 241-C-101

The leak volume estimate for SST C-101 was decreased from 20,000 gal to 1,000 gal (HNF-EP-0182). The previous estimate is based on a 4–in. liquid-level decrease from 194.5 to 190.5 in. observed between January 1968 and December 1969 (approximately 23 months) when this tank contained aged PUREX waste (RPP-20820). Between January 1970 and October 1973, the surface level continued to decrease from 43.5 to 39 in. for a total decrease of 8.5 in. At 2,750 gal/in, this equates to 23,000 gal.

A 20,000 gal loss of this waste type would have released approximately 127,000 Ci of ^{137}Cs (BHI-01496), more than all of the ^{137}Cs projected to have been lost from all of the SX tank farm leaks (RPP-6285). The spectral gamma logging data from drywells around SST C-101 show little contamination and nothing of that order of magnitude. According to documents written in 1998 and 2001 (GJO-HAN-18, *Hanford Tank Farms Vadose Zone C-Tank Farm Report* and RPP-8321, *Analysis & Summary Report of Historical Drywell Gamma Logs for the 241-C Tank Farm 200 East Area,* respectively) four drywells surround the SST C-101 waste tank (30-01-01, 30-01-06, 30-01-09, and 30-01-12). Of these, 30-01-06 and 30-01-09 have shown radioactive contamination of ^{137}Cs, ^{60}Co, and ^{106}Ru -- especially in drywells 30-01-06 and 30-01-09, located near the south and southwest sides of the tank. However, the amount of radioactive contamination detected (the highest amount equaling approximately 1,000 pCi/g) is not great enough to conclude that the contamination is from a leak of 20,000 gal of highly radioactive PUREX acid waste (PAW).

The maximum leak volume accounted for in drywell measurements in the entire C tank farm was calculated to be 18,620 m^3 and 7.32 Ci (GJO-HAN-18, Addendum). Even this estimate for the entire C tank farm is a fraction (5.8E-5) of the 127,000 Ci that would occur for a 20,000 gal leak of PAW. Multiplying this fraction by 20,000 gal equals less than 2 gal of PAW accounted for by drywell measurements and plume size estimates. In following a protocol for a minimum value for leak volumes in Group 3, a 1,000-gal nominal estimate of PAW was assumed for performance assessments.

Given the current understanding of fluid-flow in Hanford's unsaturated soils, it is highly unlikely that a leak volume of 20,000 gal of PAW could have gone undetected by the secondary leak monitoring (i.e., the drywell gross gamma logging) system. At the time of the apparent liquid losses from this tank, the tank held wastes recently transferred from A tank farm boiling waste tanks. For that mission, the first six tanks in the C tank farm were fitted with air condensers to help dissipate heat generated from radionuclide decay. During the time C tank farm tanks were used to store aged PUREX supernatant, large liquid-level decreases were recorded in a number of tanks and these liquid-level decreases were attributed to evaporative cooling (WHC-MR-0132). Thus, evaporative cooling likely accounts for much of the liquid-level decrease in this tank. Evaporation calculations (Larkin 1969, "East Area Ion Exchange Feed Sources") show that SST C-101 liquid waste ^{137}Cs concentration at the time of the first observed liquid-level decrease was 3.85 Ci/gal, sufficient to evaporate up to 550 gal/month. The 4-in. liquid-level decrease was observed over a 23-month period (January 1968 to December 1969) (RHO-CD-896, *Review of Classification of Nine Hanford Single-Shell "Questionable Integrity" Tanks*). At the heat rates presented in Larkin (1969), there would have been a potential 126,000 gal or 4.6 in. (126,000/2,750 gal/in) of evaporation in 23 months. This estimate does not include other heat sources in the aged PUREX waste. Therefore, all of the liquid-level decrease may be accounted for by evaporation.

A nominal 1,000 gal leak of PAW is assumed based on:

- Worst-case vadose zone measurements and calculations that indicate less than 2 gal of PAW in the vadose zone, and
- Evaporation calculations that account for all of the liquid-level decrease.

3.3.4 Single-Shell Tank 241-SX-110

The estimated leak volume for SST SX-110 was reduced from 5,500 gal to a nominal 1,000 gal. SST SX-110 was classified as an assumed leaker in 1976 with a leak volume of 5,500 gal based on a 2-in. liquid-level decrease (HNF-EP-0182).

Waste status summary reports for 1971 through 1976 and WHC-MR-0132 show that the tank contained a sludge heel of REDOX HLW at the time of the leak. From 4th quarter 1975 through 2nd quarter 1976, SST SX-110 received a variety of waste from 200 East Area tanks (B-103, BX-103, BX-105, and 241-302B catch tank). In 1975 through 1976, miscellaneous supernatants were consolidated in these tanks and then transferred to SST SX-110 for staging as feed to the 242-S Evaporator. The waste was identified as a mixture of waste types including ion-exchange waste (cesium depleted waste from the B Plant ion-exchange process), 224 waste (lanthanum fluoride finishing waste), evaporator bottoms, REDOX HLW sludge, and waste from the 300 Area laboratory. There also was likely PUREX coating removal waste and N Reactor decontamination waste mixed in with other waste types given the various transfers and collecting supernatants from numerous tanks in SSTs B-103, BX-103, and BX-105 for transfer to SST SX-110. In the 3rd quarter of 1976, the integrity of SST SX-110 was suspected and all pumpable supernatant was removed.

A 1,000 gal loss of this waste type mixture would result in high levels of radioactivity in tank laterals (HNF-5782). However, little or no activity was found in the spectral gamma logging drywell data (GJPO-HAN-4, *Vadose Zone Characterization Project at the Hanford Tank Farms, SX Tank Farm Report*) or in gross gamma logging data from the laterals 10 ft below the bottom of the tank (HNF-5782).

The 5,500-gal leak volume estimate for SST SX-110 appears to be based on a 2 in. decrease in the tank liquid-level manual tape measurements observed between August 23, 1974, and September 24, 1974. A comprehensive review of the liquid-level decrease was conducted in 1980 (RHO-CD-896). The 1980 study notes that three occurrence reports concerning SST SX-110 were issued. One for a 1-in. liquid-level decrease in September 1974 following a transfer completed August 23, 1974, which exceeded the leak detection criterion of 1.5 in/wk. The second in January 1975 for a rise of radiation levels at the 53 to 57 ft level in drywells 41-10-08 and 41-11-03. The third for a 0.75-in. liquid-level decrease in 7 days observed June 1976. All of these occurrence reports concluded that SST SX-110 was a "sound" tank. However, questions continued regarding the status and it was designated questionable integrity.

Three groups evaluated available information independently: (1) a tank farm surveillance group, (2) tank farm process control group, (3) and effluent controls group to determine if SST SX-110 should be classified a confirmed leaker. Following an initial review, all three groups recommended that the tank continue to be classified as questionable integrity. At a 95% confidence level, only the tank farm surveillance group recommended reclassifying the tank as a confirmed leaker concluding "the tank did leak during 1974 at a high-liquid level, likely above the 340-in. Level." However, the groups also stated that "the level additions exceeding the 340-in. level and the apparent psychometric liquid-level decreases (i.e., evaporation) could have masked a tank leak." It was noted that the last evaporative water from SST SX-110 was reported in April-June 1966 (ISO-404, *Chemical Processing Division Waste Status Summary April 1, 1966 Through June 30, 1966*). No evaporative water losses are reported for this tank after June 1966 (see ISO-538, *Chemical Processing Division Waste Status Summary July 1, 1966 Through September 30, 1966;* ISO-674, *Chemical Processing Division Waste Status Summary October 1, 1966 Through December 31, 1966*; ISO-806, *Chemical Processing Division Waste Status Summary January 1, 1967 Through March 31, 1967*; ISO-967, *Chemical Processing Division Waste Status Summary April 1, 1967 Through June 30, 1967*).

None the less, the chief scientist concluded that: ".. alone the liquid level decreases would normally be strong evidence that Tank 110-SX is a leaker, but there appears to be little, if any, dry well or lateral monitoring information to support the hypothesis that Tank 110-SX is indeed a leaker. In fact, all lateral and/or dry well readings can be accounted for by other means. Furthermore, a perfectly rational and acceptable explanation for liquid level decreases noted in August-September 1974 and in 1976 is to be found in the high heat content of the sludge in Tank 110-SX and resulting evaporation losses through the sludge cooling system".

The purpose of this report is to provide a reasonable leak volume estimate for tank performance assessments. Based on lateral measurements directly under the tank and results presented in the 1980 study, an estimate of 5,500 gal, which would attribute the entire liquid-level decrease to a tank leak, is not reasonable. An estimate of "0" leak also cannot be proven. Therefore, pending additional characterization data, a nominal leak volume of 1,000 gal was assumed.

3.3.5 Single-Shell Tank 241-SX-112

The estimated leak volume for SST SX-112 was reduced from 30,000 gal to a nominal 1,000 gal. SST SX-112 was classified as an assumed leaker in 1976 with a leak date of 1969 and a leak volume of 30,000 gal (HNF-EP-0182).

SST SX-112 was used to store REDOX boiling waste. This tank was first filled with REDOX HLW in 1956, most liquids were removed in 1960, and then refilled with REDOX HLW. Again, most liquids were removed in 1966 and the tank again received REDOX HLW. Over the time period from 1956 till 1969 many hundreds of thousands of gallons of water were lost from this tank through evaporative cooling and replaced with water or stored REDOX condensate. Finally, in the 1st quarter of 1969, 498,000 gal of aged REDOX HLW was removed from this tank. Also shown in the waste transfer records (LA-UR-97-311) are two liquid-level decreases, one (32,000 gal) attributed to REDOX condensate loss from evaporative cooling, and the second (31,000 gal) to a potential tank leak. In-tank photographs taken in 1974 show a 3 in.-wide crack in the steel liner 17 ft above the tank base (34 ft bgs) (SD-WM-TI-356) and a bulge in the steel liner (RHO-R-39, *Boiling Waste Tank Farm Operational History*). Thus, it is likely the steel liner was breached sometime during the time REDOX HLW was stored in this tank leading to potential tank leaks.

A 30,000-gal leak of REDOX HLW would be expected to result in the loss of high levels of radioactivity (an estimated 40,000 Ci of ^{137}Cs) (HNF-5782; HNF-EP-0182) to the soil column. There are nine drywells drilled close to the edge of this tank and three laterals under the tank that were used as a secondary leak detection system. Spectral gamma logging of drywells around SST SX-112 identified two drywells (41-12-02 and 41-12-03) with peak ^{137}Cs gamma activities of about 1.0E+08 and 1.0E+05 pCi/g, respectively. However, the peak gamma activity is approximately 20 ft below the base of SST SX-112. Based on gamma activity of other drywells in this area, the ^{137}Cs activity found in these two drywells (41-12-02 and 41-12-03) is believed to have originated from the SST SX-108 leak events (RPP-7884).

Only one of three laterals (lateral 44-12-02) under SST SX-112 shows gamma activity (SD-WM-TI-356; GJ-HAN-14). The location of this gamma activity is consistent with a tank leak; however, the gamma activity is significantly lower than would be expected for a 30,000-gal leak of REDOX HLW. A 30,000-gal leak involving REDOX HLW would have left a ^{137}Cs activity "footprint" similar to that found around SSTs SX-107 and SX-108 (RPP-7884). Thus, the gamma logging data around and under SST SX-112 is inconsistent with the "1969 leak event scenario."

Following is a more detailed discussion of the waste transfer records for SST SX-112 that suggest a reason for apparent inconsistency between gamma logging measurements and the 1969 leak event scenario. The waste data summary records show that from January through June 1966, no boil-down or tank waste evaporation was observed (ISO-226, *Chemical Processing Division Waste Status Summary January 1, 1966 Through March 31, 1966*; ISO-404). Between July and September 1966, the tank received 292,000 gal of REDOX waste from 202-S (ISO-538) also from July through September 1966, 220,000 gal of boil down occurred (ISO-538). From October through December another 35,000 gal of boil-down is reported (ISO-674). Also, during the fourth quarter of 1966, the tank received 65,000 gal of supernatant and 300,000 gal of water (ISO-674). The added water accounts for more than one-half the waste volume in the tank at that point in time. Following this transfer, "0" boil down was reported up to December 1967, after which boil down was not recorded in the waste status summaries. No additional waste was added to or transferred from SST SX-102 until the 4th quarter of 1966 when 21,000 gal of supernatant from SST SX-107 was added.

Transfer records (LA-UR-97-311) appear to be inconsistent with the waste status summaries, showing an R condensate loss of 335 kgal in 4th quarter 1966, but no reference or basis for this is presented.

The liquid level decrease was observed just after the SST SX-107 transfer. The level of waste in the tank prior to the water transfer was 596 kgal (222 in). This is just above the level of the liner crack (204 in). Therefore, the previously estimated 30,000 gal leak may have been mostly water with some SST SX-107 supernatant and little or no REDOX supernatant.

The portion of water vs. waste leaked and activity associated with the waste leaked is unknown other than the levels of activity observed in the vadose zone. However, the activity level measured in the vadose zone is well below what would be expected if even a one-thousand gallon leak of R Supernatant occurred. Therefore, a nominal leak volume of 1,000 gal of R supernatant was assumed to estimate contaminant inventories.

3.3.6 Single-Shell Tank 241-U-101

The leak volume estimate for SST U-101 was reduced from 30,000 gal to 5,000 gal of REDOX liquid waste. SST U-101 was removed from service as a confirmed leaker in 1959 (HNF-EP-0182, SD-WM-TI-356). However, no information could be found documenting a leak event or occurrence report for the tank. Tank transfer records show unexplained liquid-level decreases from a level of 540,000 to 516,000 gal in the tank between the second quarter of 1958 and the second quarter of 1960 before liquids were removed leaving 26,000 gal of solids. However, the four drywells within 15 to 18 ft of SST U-101 (60-00-02, 60-01-08, 60-01-10, and 60-04-12) show minimal surface contamination from 0 to 20 ft belowgrade (< 10 pCi/g) activity, but no elevated activity was found below 20 ft (GJ-HAN-33).

An analysis of the heat load generated by the waste in SST U-101 at the time of the liquid losses would support assigning some losses to "evaporative cooling" (RPP-15808). Metal waste was emptied from SST U-101 in 1957 and then refilled in 1958 with REDOX (R1) HLW supernatant transferred from SST SX-103. However, the R1 supernatant stored in SST SX-103 was not identified in any of the tank farm waste status summary reports as being self concentrating or boiling waste. SST SX-103 process records show a steady waste volume of 943,000 to 941,000 gal between August 1955 and April 1958, indicating that there was little evaporation in the waste transferred.

Because little leak information was found and drywell data is inconsistent with a 30,000 gal leak, an estimate of a likely maximum leak volume that could go undetected in drywells was applied. The likely maximum leak volume or "de-minimus" volume for drywells is estimated to be 5,000 gal. This volume was determined from an evaluation of data collected at a field test site and complemented by the study of other large and well documented tank leaks (see Appendix A). The 5,000 gal estimate will vary depending on the distance of drywells from the tank, vadose zone characteristics, and the level of activity in the waste.

Further characterization of SST U-101 is planned.

3.4 GROUP 4 TANKS

Group 4 consists of 18 tanks (AX-104, B-101, B-103, B-105, B-111, BX-110, BX-111, BY-105, BY-106, SX-114, T-107, TX-105, TX-110, TX-113, TX-114, TX-115, TX-116 and TX-117) (Table 3-1). Little information is available for these tanks to support a leak volume estimate and no previous leak inventory estimate has been developed. Also, no leak volume estimate has been developed for these tanks other than to assume an average value based on previous tank leaks from 18 other tanks (8901832B, "Single-Shell Tank Leak Volumes"). The average leak volume estimate in HNF-EP-0182 for these tanks was based on an assumption that their cumulative leakage is approximately the same as for 18 of the 24 tanks where leak volumes were determined by liquid-level decreases. SSTs SX-110 and T-106 were considered atypical and were not included. SSTs B-201, -203, -204, and C-203, also excluded, are small 200-series diameter tanks. The 18 tank leak estimates that were included in the estimate were SSTs A-103, AX-102, B-107, B-110, BY-107, C-101, C-111, S-104, SX-104, SX-109, T-103,

T-108, T-109, T-111, TY-101, TY-104, U-110, and U-112 (8901832B). The total liquid-loss assumed for the 19 tanks was 150,000 gal, an average of approximately 8,000 gal/tank.

However, for these tanks, small levels of contamination (much smaller than plumes for typical tank leaks; tanks in Group 1) were observed in nearby drywells. Drywell measurements for these tanks are presented in the DOE Grand Junction reports (Table 2-1) and summarized in Table 3-1.

The contamination may have come from a tank or from near-surface releases or other sources. Therefore, neither the waste type and source of the drywell activity nor the date when it occurred are known; all of which are needed to determine a credible inventory estimate. A key distinction between these 18 tanks and tanks in Group 3 is that unexplained liquid-level decreases were observed for tanks listed in Group 3, but no unexplained liquid-level decreases were observed for the 18 tanks in Group 4. The only indication of contamination and the basis for classifying the tanks as "questionable leakers" were gamma monitoring specs found in drywells near the tanks.

While there is no basis for an inventory estimate, it was assumed that any inventory for these tanks is likely negligible. The assumption that leak inventories for these tanks are negligible was based on a review of the level and depth of contamination measured in wells near these tanks (Table 3-1). Most measurements were below 10 pCi/g and may have been instrument noise. In many cases, contamination was observed once and was not found in more recent investigations, indicating it may have been a short-lived radionuclide and not ^{137}Cs as would be expected from a tank leak or that previous specs measured were suspect. Also, the low-activity levels were often measured near the ground surface, precluding a tank leak as the contaminant source.

A worst-case plume inventory was estimated based on the distance between drywells, the distance from drywells to the tank, and the depth(s) of contamination measured (Table 3-1). With a few exceptions, even if the maximum concentration observed in drywells near the 18 tanks in this group extended the entire measured distance of the drywell, with a plume radius the distance from the tank to a drywell, the calculated inventory would be < 1 Ci and values for many drywells would be < 0.1 Ci. This was assumed negligible for risk assessments. A few of the worst-case values in Table 4-2 were > 1 Ci, but as shown, these were attributed to surface contamination and not to a tank leak.

An example calculation follows:

Drywell 11-04-01 is located 3 ft from SST AX-104. The worst-case plume estimate as defined in this rough calculation for comparison purposes is:

$$\text{Volume (ft}^3\text{)} = (\pi r^2)h \qquad (3\text{-}1)$$

Where:

r = distance of borehole from the tank (3 ft)
h = measured height in borehole (17 ft)

$$\pi(3)^2 * 17 = 480\ ft^3$$

Maximum concentration = 13.3 pCi/g
Assume maximum soil density = 1.8 g/cm^3

$$Ci = 480(ft^3) * 13.3\ pCi/g * 1.8\ g/cm^3 * 28.317\ \underline{cm^3}/ft^3 * 10^{-12}\ Ci/pCi = 3.26E\text{-}4\ Ci$$

Drywells with worst-case plume calcs exceeding 1 Ci were drywell 21-10-05 near SST BX-110 and drywells 21-11-03 and 21-11-4 near SST BX-111 at depths > 40 ft bgs. High ^{137}Cs concentrations were measured in these drywells. Although concentrations were high, they were limited to a narrow band (< 10 ft) for all three drywells, which appears to be a result of contaminant migration during excavation or drilling. More realistic plume estimates for the narrow band widths would be < 1 Ci.

In summary, there is no basis for an inventory estimate for these 18 tanks, and the inventory associated with contamination from these tanks is assumed to be negligible compared to the inventory for tank/ancillary equipment leaks in groups 1, 2 and 3. Therefore, no leak volume or leak inventory estimate was determined for tanks in Group 4.

Table 3-1. Maximum ^{137}Cs Concentrations Measured in Drywells Near Group 4 Tanks. (5 sheets)

Tank	GJO-RPT	Drywell	Dist.from tank (ft)	^{137}Cs (ft)	Max. conc. (pCi/g)	Depth (bgs) (ft)	Worst-case est. (Ci)	Comment*
241-AX-104	GJ-HAN-52	(11-04-01)	3 N-NE	0 – 17	13.3	1.5	3.26E-04	Near surface
		(11-02-10)	6 E	0 – 53.5	7.3	1.5	2.25E-03	Near surface, potential noise
		(11-04-05)	8 S-SE	0 – 10.5	9.8	4	1.05E-03	Near surface, potential noise
		(11-04-07)	50 S-SW	0 – 5.5	34	1	7.48E-02	Near surface
		(11-04-19)	3 S-SW	0 – 24.5	11.9	1.5	4.20E-04	Near surface
		(11-04-08)	2 SW	0 – 4	5.9	1	1.51E-05	Near surface, potential noise
		(11-04-10)	8 W-NW	0 – 39.5	1,456	3.5	5.89E-01	Near surface
		(11-04-11)	3 NW	0 – 17	4	6	9.79E-05	Near surface, potential noise
241-B-101	GJ-HAN-112	(20-01-01)	5 NE	4 – 45	47	41.5	7.71E-03	---
		(20-01-03)	9 E	0 – 2	7	0	1.81E-04	Near surface, potential noise
		(20-01-05)	12 SE	0 – 8	3	0	5.53E-04	Near surface, potential noise
		(20-01-06)	1 S	0 – 59.5	5	30	4.76E-05	Near surface, potential noise
		(20-00-05)	19 S	0 – 143	30	56	2.48E-01	---
		(20-01-07)	11 SW	0 – 23.5	1	23.5	4.55E-04	Potential noise
		(20-04-03)	16 W	0 – 32	50	16	6.56E-02	Near surface
		(20-01-11)	4 NW	0 – 22	382	5.5	2.15E-02	Near surface
241-B-103	GJ-HAN-114	(20-03-02)	3 NE	0 – 111.5	17.8	0	2.86E-03	Near surface
		(20-03-03)	5 E	0 – 47.5	13.5	6	2.57E-03	Near surface, potential noise
		(20-03-06)	4 S	1 – 42	23	3	2.41E-03	Near surface
		(20-03-09)	4 W	0 – 22	6.7	0	3.77E-04	Near surface potential noise
		(20-03-11)	5 NW	0 – 100.5	50	50	2.01E-02	---
241-B-105	GJ-HAN-126	(20-02-09)	15 E	0 – 99	34	0	1.21E-01	Near surface
		(20-05-06)	7 S	0 – 120	600	50	5.65E-01	---
		(20-08-03)	15 W	0 – 21	14	2	5.04E-02	Near surface
		(20-06-06)	15 N	0 – 100	230	100	8.28E-01	---

Table 3-1. Maximum ^{137}Cs Concentrations Measured in Drywells Near Group 4 Tanks. (5 sheets)

Tank	GJO-RPT	Drywell	Dist.from tank (ft)	^{137}Cs (ft)	Max. conc. (pCi/g)	Depth (bgs) (ft)	Worst-case est. (Ci)	Comment*
241-B-111	GJ-HAN-132	(20-08-09)	14 E	0 – 130	1.25	4	5.10E-03	Near surface, potential noise
		(20-00-09)	44 SW	0 – 122	12.4	0	4.69E-01	Near surface
		(20-11-09)	9 W	0 – 37.5	8	1	3.89E-03	Near surface potential noise
		(20-12-06)	16 N	0 – 102	4	5	1.67E-02	Near surface, potential noise
241-BX-110	GJ-HAN-103	(21-10-01)	6 NE	0 – 91	60	40	3.15E-02	---
		(21-10-03)	7 E	0 – 100	4,000	8	3.14E+00	Near surface
		(21-10-05)	5 SE	0 – 98	4,200	62	1.65E+00	Isolated, narrow band
		(21-00-07)	22 S	1 – 71.5	10	2.5	5.46E-02	Near surface, potential noise
		(21-10-07)	4 SW	0 – 98	1.6	1	4.02E-04	Near surface, potential noise
		(21-10-11)	4 NW	0 – 34	1	8	8.71E-05	Near surface
241-BX-111	GJ-HAN-104	(21-12-05)	25 NE	0 – 3.5	3.1	0	1.09E-03	Near surface
		(21-11-03)	7 E	0 – 98.5	10000	42	7.72E+00	Isolated, narrow band
		(21-11-04)	3 SE	0 – 82.5	10000	40	1.19E+00	Isolated, narrow band
		(21-11-05)	3 SE	0 – 64.5	16.7	43	1.55E-03	---
		(21-11-07)	2 SW	0 – 98.5	0.61	1	3.85E-05	Near surface, potential noise
		(21-00-09)	41 SW	0 – 74	0.58	1.5	1.15E-02	Near surface, potential noise
		(21-00-21)	43 SW	0 – 144	2.27	43	9.67E-02	Potential noise
		(21-00-22)	67 SW	0 – 72.5	0.52	17.5	2.71E-02	Near surface
		(21-11-10)	3 NW	0 – 1.5	0.22	1	4.75E-07	Near surface
		(21-11-11)	2 NW	0 – 4	7.2	0.5	1.84E-05	Near surface
241-BY-105	GJ-HAN-22	(22-05-01)	6 NE	0 – 98	10000	2	5.65E+00	Near surface
		(22-05-05)	6 SE	0 – 97	20	0.5	1.12E-02	Near surface
		(22-05-09)	7 W	0 – 98	1	0 – 98	7.69E-04	Potential noise

Table 3-1. Maximum ^{137}Cs Concentrations Measured in Drywells Near Group 4 Tanks. (5 sheets)

Tank	GJO-RPT	Drywell	Dist.from tank (ft)	^{137}Cs (ft)	Max. conc. (pCi/g)	Depth (bgs) (ft)	Worst-case est. (Ci)	Comment*
241-BY-106	GJ-HAN-23	(22-06-01)	6 NE	0 – 100	1	0 – 100	5.76E-04	Potential noise
		(22-03-09)	21 E	0 – 48	NR	---	---	---
		(22-06-05)	7 SE	0 – 45	1	0 – 45	3.53E-04	Potential noise
		(22-06-07)	23 SW	0 – 150	20	48	2.54E-01	---
		(22-06-09)	6 W	0 – 100	1	0 – 100	5.76E-04	Potential noise
		(22-06-11)	9 NW	0 – 37	10	37	4.80E-03	Potential noise
241-SX-114	GJ-HAN-16	(41-14-02)	10 NE	0 – 76.7	4	76.7	4.91E-03	Potential noise
		(41-14-03)	12 E	0 – 75	4.5	75	7.78E-03	Potential noise
		(41-14-04)	16 SE	0 – 123.7	10	0	5.07E-02	Near surface
		(41-14-06)	13 S	0 – 76	1	76	2.06E-03	Potential noise
		(41-14-08)	12 SW	0 – 66	1	0 & 66	1.52E-03	Potential noise
		(41-14-09)	11 W	0 – 75	NR	---	---	---
		(41-14-11)	9 NW	0 – 75	1	0 – 10 & 70 – 75	9.72E-04	Potential noise
		(41-11-06)	10 N	0 – 75	20	60 – 75	2.40E-02	---
241-T-107	GJ-HAN-1	(50-07-03)	5 E	0 – 17	4	17	2.72E-04	Potential noise
		(50-07-07)	14 S-SW	0 – 45	13	45	1.84E-02	---
		(50-07-08)	12 W	0 – 15	2	6	6.91E-04	Near surface, potential noise
		(50-04-05)	16 NE	0 – 95	20	5	7.78E-02	Near surface
		(50-04-07)	16 NW	0 – 40	120	5	1.97E-01	Near surface
241-TX-105	GJ-HAN-47	(51-00-03)	3 NE	0 – 100	17.5	8.5	2.52E-03	Near surface
		(51-05-03)	7 E	0 – 113	5.4	3	4.79E-03	Near surface, potential noise
		(51-05-05)	7 SE	0 – 100	10	0	7.84E-03	Near surface, potential noise
		(51-05-07)	7 S	0 – 111	20	0	1.74E-02	Near surface
		(51-05-08)	7 W-SW	0 – 100	10	0	7.84E-03	Near surface, potential noise
		(51-05-10)	3 NW	0 – 100	10	0	1.44E-03	Near surface, potential noise

Table 3-1. Maximum ^{137}Cs Concentrations Measured in Drywells Near Group 4 Tanks. (5 sheets)

Tank	GJO-RPT	Drywell	Dist.from tank (ft)	^{137}Cs (ft)	Max. conc. (pCi/g)	Depth (bgs) (ft)	Worst-case est. (Ci)	Comment*
241-TX-110	GJ-HAN-55	(51-10-01)	6 NE	0 – 100	5	0	2.88E-03	Near surface, potential noise
		(51-09-10)	18 E-NE	0 – 105	6.4	0	3.48E-02	Near surface, potential noise
		(51-10-04)	2 E	0 – 100	38	1.5	2.43E-03	Near surface
		(51-06-12)	8 S	0 – 18	5	2	9.22E-04	Near surface, potential noise
		(51-10-08)	5 SW	0 – 100	5.3	0	2.12E-03	Near surface, potential noise
		(51-11-03)	15 W	0 – 100	5.5	10	1.98E-02	Near surface, potential noise
		(51-11-02)	23 NW	0 – 100	19.9	0	1.68E-01	Near surface
		(51-10-12)	4 N	0 – 99.5	7.7	99.5	1.96E-03	Near surface, potential noise
		(51-10-25)	4 NE	0 – 100	8.7	3	2.23E-03	Near surface, potential noise
		(51-10-13)	16 NE	0 – 100	20	1.5	8.19E-02	Near surface
241-TX-113	GJ-HAN-58	(51-13-05)	6 SE	0 – 100	5.5	99	3.17E-03	Potential noise
		(51-09-12)	11 S	0 – 100	18.6	3.5	3.60E-02	Near surface
		(51-13-08)	2 S-SW	0 – 100	4.4	0	2.82E-04	Near surface, potential noise
		(51-13-12)	6 N	0 – 99	18.8	6	1.07E-02	Near surface
241-TX-114	GJ-HAN-59	(51-14-11)	2 N	0 – 99.5	53	44	3.38E-03	---
		(51-14-04)	2 E	0 – 97.5	1,843	47	1.15E-01	---
		(51-14-08)	5 SW	0 – 98	10	3	3.92E-03	Near surface, potential noise
241-TX-115	GJ-HAN-60	(51-15-04)	5 E	0 - 94.5	10.1	7.5	3.82E-03	Near surface, potential noise
		(51-11-01)	18 S-SE	0 – 113	2.8	0	1.64E-02	Near surface, potential noise
		(51-15-07)	3 SW	0 – 99	29	1	4.14E-03	Near surface
		(51-15-09)	3 W	0 – 100	1.3	0	1.87E-04	Near surface, potential noise
		(51-15-11)	3 N	0 – 100	14.9	4.5	2.15E-03	Near surface

Table 3-1. Maximum ^{137}Cs Concentrations Measured in Drywells Near Group 4 Tanks. (5 sheets)

Tank	GJO-RPT	Drywell	Dist.from tank (ft)	^{137}Cs (ft)	Max. conc. (pCi/g)	Depth (bgs) (ft)	Worst-case est. (Ci)	Comment*
241-TX-116	GJ-HAN-61	(51-16-04)	6 E	0 – 98	40	9.5	2.26E-02	Near surface
		(51-16-07)	11 SW	0 – 101	7	0	1.37E-02	Near surface
		(51-16-11)	8 N	0 – 99	40	3	4.14E-02	Near surface, potential noise
241-TX-117	GJ-HAN-62	(51-17-02)	7 NE	0 – 99	26	0	2.02E-02	Near surface
		(51-17-10)	6 W-NW	0 - 98.5	412.8	7	2.34E-01	Near surface
		(51-17-11)	6 N	0 - 101.5	41.2	1.5	2.41E-02	Near surface
		(51-17-03)	20 NE	0 – 142.5	111.9	1	1.02E+00	Near surface

Notes:
* Measurements with a max. conc. between 0 and 20 ft are marked "near surface".
Only maximum concentrations less than 10 pCi/g are flagged as potential noise. However, measurements as high as 1,000 pCi/g may be instrument noise.
** Worst-case plume estimates for a right circular cylinder; radius = distance from tank, height = measured depth.
See example calculation.

4.0 NEAR-SURFACE CONTAMINATION IN THE SINGLE-SHELL TANK FARMS

As part of the tank farms vadose zone characterization efforts, a series of documents were prepared that examine the operational history of each of the SST farms:

- HNF-5231, *Historical Vadose Zone Contamination from B, BX, and BY Tank Farm Operations*
- RPP-5957, *Historical Vadose Zone Contamination from T, TX, and TY Tank Farm Operations*
- RPP-7494, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations*
- RPP-7580, *Historical Vadose Zone Contamination from U Farm Operations*
- HNF-SD-WM-ER-560, *Historical Vadose Zone Contamination from S and SC Tank Farm Operations.*

These documents, prepared by Fluor Federal Services, provide an overview of the structural aspects of the tank farm operations such as waste transfer piping systems and infrastructure. These documents also provide a compilation of the UPRs within the tank farm or WMA of concern. Another document reviewed to assess near surface contamination in the tank farms was the Handbook for 200 Area Waste Sites (RHO-CD-673). Each of the identified UPRs has a formal report associated with it that is retrievable over the Hanford Intranet from WIDS. Table 4-1 shows UPRs applicable to SST farm WMAs based on data in WIDS as of July 1, 2005. A second UPR number was assigned to group UPRs by tank farm or WMA. Table 4-1 does not include UPRs associated with the tank leaks previously identified in Table 2-2.

It was assumed that little or no soil contamination inventory is associated with UPRs identified as "airborne" or "particulate," and these are not included in the SIM. Volume estimates for each of the UPRs are those specified in WIDS, except as noted, where WIDS did not provide an estimate. For these, the volume estimates and basis used were based on assumptions in Table 4-1. As shown in Table 4-1, volume estimates were not provided for UPRs assumed to be small, the result of particulate, or where there was no technical basis for a volume estimate.

Future near-surface characterization efforts are scheduled for a number of the SST farms. However, as currently scoped, these efforts will only address selected near-surface waste-loss events. General characterization to better quantify near-surface contamination within a tank farm would require a much-expanded effort. The list of UPRs in tank farm areas may also change as WMAs are further defined and as ongoing Hanford Site integration studies are completed.

Table 4-1. Waste Management Area UPRs. (3 sheets)

UPR	Consolidated UPR[1]	In SIM	Waste type	Date	Volume* (gal)	Location/Comments
UPR-200-E-4	200-E-120 B-Farm	No	Cooling Water	1951	No Basis	241-B-151 diversion box UPR. Contamination removed.
UPR-200-E-6	200-E-120 B-Farm	Yes	1C2	1954	1017	241-B-153 diversion box, Volume estimate for 1 Ci of 1C waste over 5,000 ft^2. Volume assumes 1 in. depth and 0.33 soil void.
UPR-200-E-27	200-E-133 C-Farm	No	Particulate	1960	N/A	244-CR, inside tank farm fence, windblown contamination.
UPR-200-E-38	200-E-120 B-Farm	Yes	P2-CSR	1968	5,400	241-B-152 diversion box release. Volume from WIDS.
UPR-200-E-47	200-E-131 A-Farm	No	Particulate	1974	N/A	A tank farm contamination spread, failed HEPA filter 702-A
UPR-200-E-48	200-E-131 A-Farm	No	Particulate	1974	N/A	A-106 pump pit, windblown contamination.
200-E-60	Not a UPR	Yes	DW	1977	1,370	BY tank farm IMUST. Volume estimate assumes 1/3 of the vessel volume or 1,370 gal leaked during decontamination.
UPR-200-E-68	200-E-133 C-Farm	No	CWP	1968	No Basis	Not enough information to estimate a volume.
UPR-200-E-73	200-E-120 B-Farm	Yes	MW2	1951	92.5	241-B-151 diversion box release, ~10 Ci, most removed then covered. Volume for 10 Ci, MW.
UPR-200-E-74	200-E-120 B-Farm	Yes	Decon Waste	1954	10 gal	241-B-152 diversion box, 1 Ci spread 50 ft^2. Localized to personnel. Volume based on 1 Ci Decon Waste.
UPR-200-E-75	200-E-120 B-Farm	Yes	1C2	1955	1017	B-153 diversion box, ~1 Ci released over 5,000 ft^2. Volume based on 1 Ci of 1C waste, and assumes 1 in. depth and 0.33 void.
UPR-200-E-81	200-E-133 C-Farm	Yes	CWP	1969	36,000	CR-151 diversion box. WIDS Volume.
UPR-200-E-82	200-E-133 C-Farm	Yes	P2-CSR	1982	2,600	241-C-152 diversion box. WIDS Volume.
UPR-200-E-86		Yes	P2-AR	1971	18,500	C tank farm line break, 6m x 6m contamination. Volume based on 25,000 Ci ^{137}Cs, 1.35 Ci/gal.
UPR-200-E-105	200-E-132 BX/BY-Farm	Yes	1C2	1952	23,000	BY-107 manifold header. WIDS volume.
UPR-200-E-107	200-E-133 C-Farm	Yes	TBP-UR	1952	5	244-CR vault. WIDS volume.
UPR-200-E-108	200-E-120 B-Farm	Yes	MW2	1953	196	B-102 to B-101 transfer line small spill, but visible. Volume

Table 4-1. Waste Management Area UPRs. (3 sheets)

UPR	Consolidated UPR[1]	In SIM	Waste type	Date	Volume* (gal)	Location/Comments
						calculated based on 10 rad/hr, 10 ft radius, assumes 1 in. depth and 0.33 void.
UPR-200-E-109	200-E-120 B-Farm	Yes	TBP-UR	1953	150	B-104 pump float jam, riser spill. WIDS volume.
UPR-200-E-110	200-E-132 BX/BY-Farm	Yes	1C2	1955	5,086	BY-112 valve pit release, Volume based on 25,000 ft^2 (WIDS) assumes 1 in. depth and 0.33 void.
UPR-200-E-115	200-E-131 A-Farm	No	PUREX	1974	No Basis	AX-103 pump pit spray, small volume on employee and ground.
UPR-200-E-116	200-E-132 BX/BY-Farm	No	BY Salt	1972	No Basis	BY-112 pump pit caustic flush water, 3 rad/hr Sr and Cs.
UPR-200-E-118	200-E-133 C-Farm	No	Particulate	1957	N/A	C-107 airborne tank release caused ground contamination
UPR-200-E-119	200-E-131 A-Farm	No	P2-AR	1969	0.03	AX-104 surface contamination, contaminated tools set on ground.
UPR-200-E-145	200-E-131 A-Farm	Yes	P3	1993	1650	Pipeline leak, east of A tank farm entrance, 3m x 6m. WIDS Volume for 30 55-gal drums.
UPR-200-W-12	200-W-94 TX/TY-Farm	Yes	1C Evap	1951	5	Riser leak S of 242-T, inside T tank farm. WIDS states "a few gallons", assume 5 average and 10 max.
UPR-200-W-17	200-W-94 TX/TY-Farm	No	1C	1952	No basis	Not enough information for a volume estimate. Appears negligible.
UPR-200-W-24	200-W-95 U-Farm	Yes	MW1	1953	36	244-UR vault release. One in. diameter column 30 ft high for 30 seconds (WIDS). Volume estimate assumes one column volume is replaced every second for 30 seconds.
UPR-200-W-49	200-W-96 S/SX/SY-Farm	No	Particulate	1958	N/A	Windborne particulate from SX tank farm.
UPR-200-W-50	200-W-96 S/SX/SY-Farm	No	Particulate	1958	N/A	Windborne particulate from SX tank farm.
UPR-200-W-80	200-W-96 S/SX/SY-Farm	No	Particulate	1978	N/A	S/SX tank farms windborne.
UPR-200-W-81	200-W-96 S/SX/SY-Farm	No	Particulate	1973	N/A	Radioactive specs in S/SX tank farms from contaminated equipment
UPR-200-W-100	200-W-94 TX/TY-Farm	Yes	1C2	1954	2,543	Inside TX tank farm, TX-105 to TX-118 line leak. WIDS states

Table 4-1. Waste Management Area UPRs. (3 sheets)

UPR	Consolidated UPR[1]	In SIM	Waste type	Date	Volume* (gal)	Location/Comments
						~10 Ci. 12,500 ft^2 covered. Volume assumes 1 in. depth and 0.33 void.
UPR-200-W-126	200-W-94 TX/TY-Farm	No	Particulate	1975	N/A	241-TX-153 airborne. Employee contaminated
UPR-200-W-127	200-W-96 S/SX/SY-Farm	Yes	R2	1980	87	Liquid pool from 242-S evaporator inside S tank farm fence. Volume assumes a 1 m^3 pool with a 0.33 void.
UPR-200-W-128	200-W-95 U-Farm	No	R1	1971	No Basis	U-103 tank pit waste line, employees cut it and were contaminated.
UPR-200-W-129	200-W-94 TX/TY-Farm	No	1C1	1971	No Basis	TX tank farm pump pit personnel contamination
UPR-200-W-132	200-W-9 U-Farm	Yes	MW2	1956	500	241-UR-151 diversion box release. WIDS volume.

Notes:

* WIDS volume estimates are as of March 1, 2005.

1. Consolidated UPRs:
200-E-120 Contamination Migration from 241-B Tank Farm,
200-E-131 Contaminated Soil Associated with 241-A Tank Farm,
200-E-132 BX/BY Tank Farm Contaminated Soil, 200-E-133 Contaminated Soil at C Tank Farm,
200-E-134 Contaminated Soil at 241-AW Tank Farm,
200-W-93 Contaminated Soil at 241-T Tank Farm,
200-W-94 Contaminated Soil at TX/TY Tank farm,
200-W-95 Contaminated Soil at U-Tank Farm,
200-W-96 Contaminated Soil at 241-S/SX/SY Tank Farm.

1C1 = first cycle decontamination waste from the $BiP0_4$ process, 1944 to 1951.
1C2 = first cycle decontamination waste from the $BiP0_4$ process, 1952 to 1956.
AR = washed PUREX Sludge
CSR = cesium recovery.
CWP = cladding waste, PUREX.
DW = decontamination Waste
HEPA = high-efficiency particulate air (filter).
MW1 = metal waste from $BiPO_4$, 1944 to 1951
MW2 = metal waste from $BiPO_4$, 1952 to 1956.
N/A = not applicable.
P2 = PUREX high-level waste, 1963 to 1967
P3 = PUREX high-level waste to AZ-101
PUREX = plutonium/uranium extraction.
R1 = REDOX waste, 1952 to 1957
R2 = REDOX waste, 1958 to 1966
SIM = Soil Inventory Model.
TBP = tributyl phosphate.
UR = Uranium Recovery
UPR = unplanned release.
WIDS = *Waste Information Data System*.
WMA = Waste Management Area.

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APPENDIX A

ESTIMATING DE-MINIMUS LEAK VOLUME FOR A SINGLE-SHELL TANK LEAK

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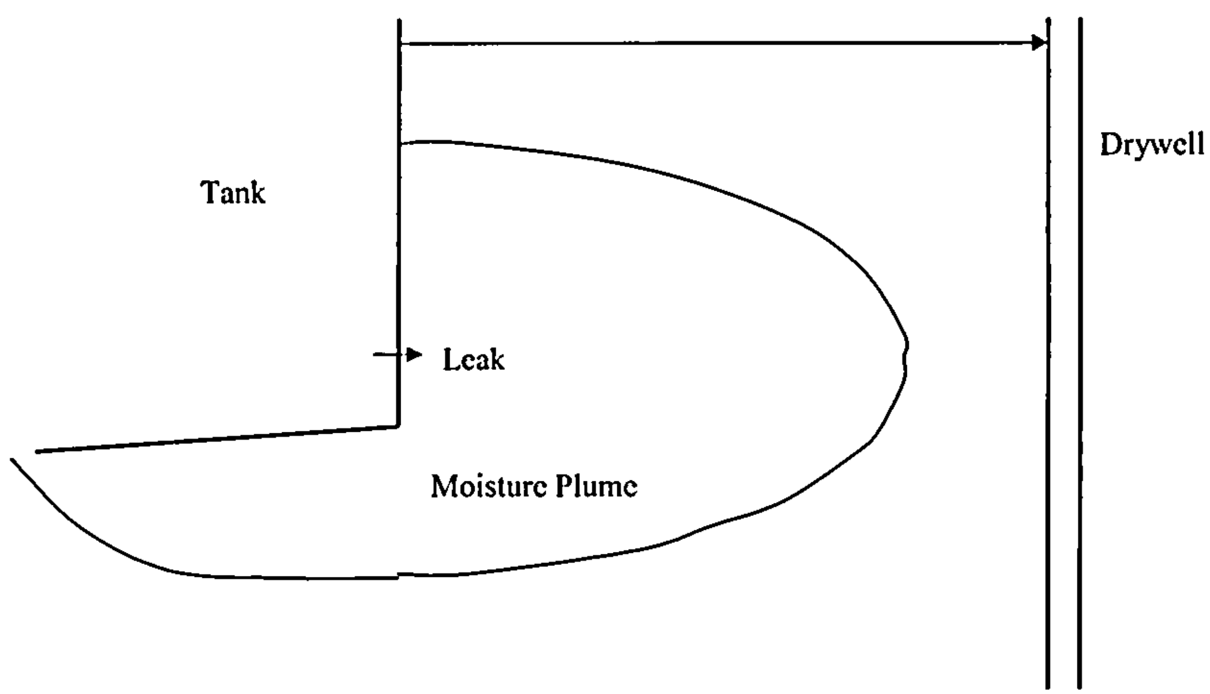
At the Hanford Site, there has been considerable interest on establishing a minimum leak volume that could be detected by the surrounding drywells. This appendix presents a discussion of: (a) a simple geometric model proposed for leak detection in the early 80's; the so-called Issacson approach (RHO-ST-34, *A Scientific Basis for Establishing Dry Well Monitoring Frequencies*); (b) results of a recent controlled field experiment at the Sisson and Lu site in the 200 East Area conducted as part of gaining additional insight on the dynamics of moisture plume from a simulated tank leak; and (c) how the evolving moisture plume data from the controlled field experiment is used as a template and extrapolated to a hypothetical 100-series tank such that the fluid injections would mimic a series of relatively low-volume "tank leaks." The appendix concludes with a discussion of limitations of the extrapolation process.

According to the Issacson approach, which is an adaptation of a simple geometric model, the liquid that has leaked is distributed within a prescribed (e.g., an ellipsoidal) volume of wetted soil centered at the leak. This is illustrated in Figure A-1. In this approach, the travel time from the leak to a nearby drywell is assumed to be proportional to the volume of soil contaminated times the increase in volumetric moisture content divided by the tank leak rate. The greater the distance from the leak to the drywell, the longer the plume takes to arrive.

Figure A-1. Schematic of Geometric Model for the Moisture Plume from a SST Leak (after Isaacson 1982)



The volume of waste that leaks from the tank, the volume of soil contaminated, and the increase in soil moisture due to the leak are given by the following three equations.

$$V_L = Q\,t$$

$$V_S = \frac{f\,4\pi\,b^3}{3g}$$

$$\Delta\theta = \frac{V_L}{V_S} = \frac{3g\,Q\,t}{f\,4\pi b^3}$$

where V_L The volume of liquid waste that leaves the tank through the leak, ft^3,
Q The average flow rate from the tank into the soil, ft^3/d; also known as the tank leak rate,
t The duration of the leak, days,
V_S The volume of the contaminated soil plume, ft^3,
f The fraction of the ellipsoid volume that is soil. The remaining volume (1-f) belongs to the tank,
b The horizontal spread of the plume, ft. The plume is assumed to spread equally in both x and y horizontal direction, unless prevented by the tank,
g The ratio of horizontal spread to the vertical spread of the plume. The volume of the ellipsoid (ignoring the tank) is $4\pi b^3/(3g)$,
$\Delta\theta$ The increase in soil moisture content due to the leak. This is the difference between the average moisture content in the plume and the moisture content in the surrounding soil.

The travel time to the drywell can be estimated by setting b=B, the distance between the leak and the drywell, and solving for leak duration.

$$t = \frac{f\,4\pi\,B^3\,\Delta\theta}{3g\,Q}.$$

The concept of a wetted plume encompassing high gamma activity regions has been used as the basis for leak volume estimates (ARH-2035, "*Investigation and Evaluation of 102-BX Tank Leak*). However, the simple geometric model of Issacson does not account for the heterogeneous media that is inherent within the Hanford formation (wherein the tanks reside). In fact, as discussed below, a recent field investigation conducted at the Sisson and Lu site provide evidence that the moisture plume from fluid injections within the Hanford formation is contrary to the idealized geometry postulated in Figure A-1. Rather, fluids discharged to the vadose zone established an evolving plume shape which is controlled by the vadose zone stratigraphy and media heterogeneities.

Controlled Field Experiment at the Sisson and Lu Site.

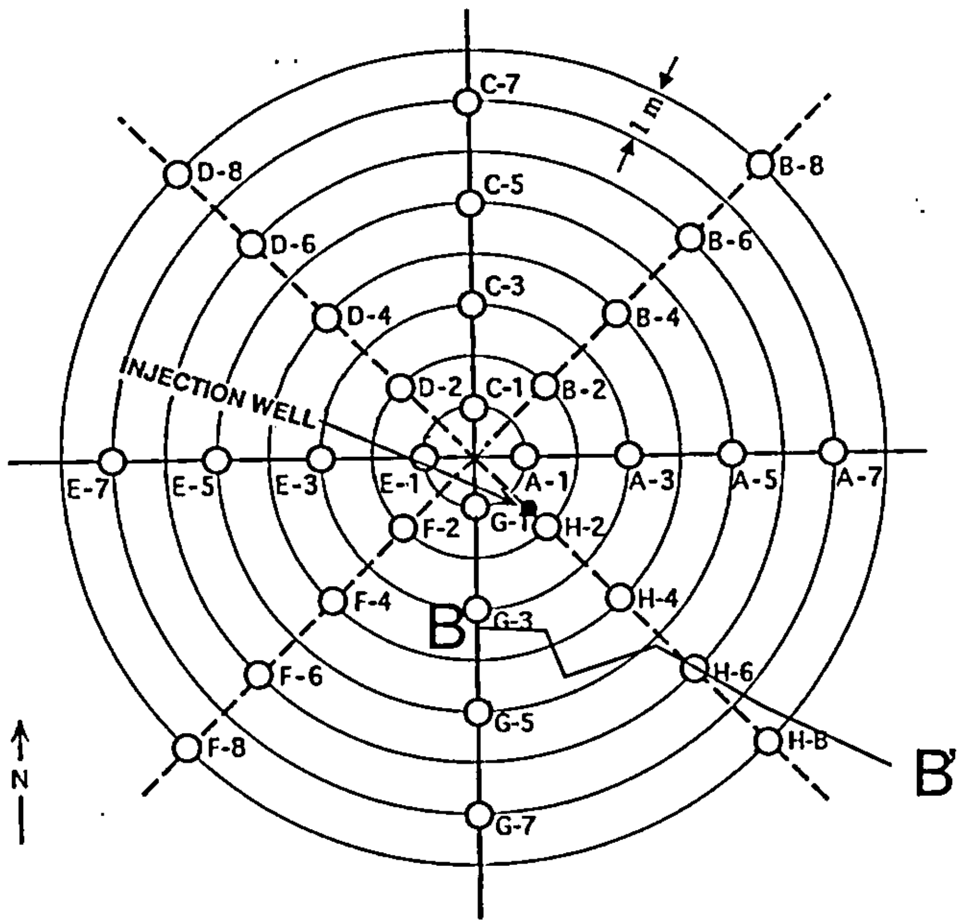
Gee and Ward (PNNL-13679, *Vadose Zone Transport Field Study: Status Report*, 2001) conducted a field injection experiment at a field site originally envisioned and designed by

Sisson and Lu (RHO-ST-46P, *Field Calibration of Computer Models for Application of Buried Liquid Discharges: A Status Report*) in the 200 East Area near the PUREX facility. The injection experiment was conducted over a 2-month period in 2000. Water content distribution was measured on May 5, 2000 at the 32 radially arranged cased boreholes (Figure A-2). Figure A-3 shows a lithostratigraphic cross-section through the Sisson and Lu site. Injections began on June 1 and 4000 L of water were metered into an injection point (point source) 5 m below the land surface over a 6-hr period. Similarly, 4000 L of water were injected in each subsequent injection on June 8, June 15, June 22, and June 28. During the injection period, neutron logging in 32 wells took place within a day following each of the first four injections. A wildfire burned close to the test site and prevented immediate logging of the moisture content distribution for the fifth injection on June 28. Three additional readings of the 32 wells were subsequently completed on July 7, July 17, and July 31. During each neutron logging, water contents were monitored at 0.305-m (12-in.) depth intervals starting from a depth of 3.97 m and continuing to a depth of 16.78 m, resulting in a total of 1344 measurements for the eight observation times over a two-month period.

A geostatistical analysis was performed to quantify the spatio-temporal evolution of the neutron probe data collected before injection, immediately following injections and during redistribution of the injected water. The details on geostatistical analyses are provided in PNNL-13679 [Gee, G. W., and A. L. Ward, *Vadose Zone Transport Field Study: Status Report*, PNNL-13679, Pacific Northwest National Laboratory, Richland, WA, 2001] and in Ye et al. (2005) [Ye, M., R. Khaleel, and T.-C. J. Yeh (2005), Stochastic analysis of moisture plume dynamics of a field injection experiment, *Water Resour. Res.*, *41*, W03013, doi:10.1029/2004WR003735]. The moisture content profiles, shown in Figure A-4 based on the geostatistical analysis, illustrate significant lateral spreading. Such behavior of the moisture plume is related to the moisture-dependent anisotropy phenomenon (Ye et al. 2005; Yeh et al. 2005). As indicated in Figure A-5, the pre- and post-injection moisture plumes are confined in a coarse-textured layer that is sandwiched between two fine-textured layers.

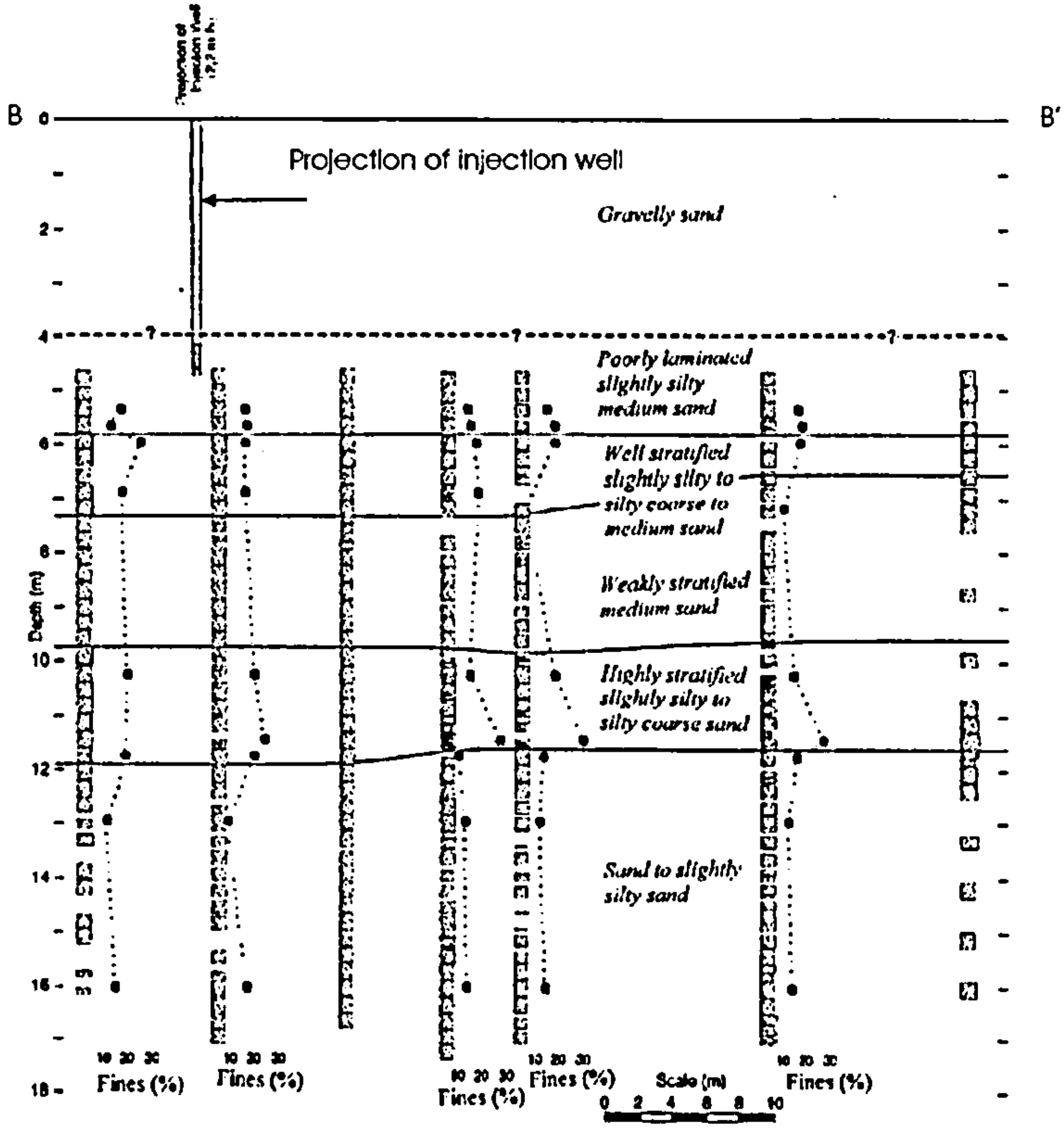
The preponderance of lateral migration is also evident elsewhere at the Hanford Site. The tank 241-T-106 tank leak (115,000 gal) is the largest known tank leak at the Hanford Site (Freeman-Pollard et al. 1994). The vadose zone profile for the T-106 leak shows that, even after 20 years of migration, the contaminant peak concentration for the long-lived mobile radionuclide is contained primarily within the fine-textured horizons at a depth of 35 to 40 m bgs and well above the water table. These field data suggest that the natural heterogeneity of the Hanford sediments plays an important role on flow and transport, and the significant lateral transport, which is induced by media heterogeneities, is highly effective in containment of plumes within the vadose zone for an extended period.

Figure A-2. Plan view of the Sisson and Lu (1984) injection test site and well numbering scheme (after Gee and Ward, 2001).



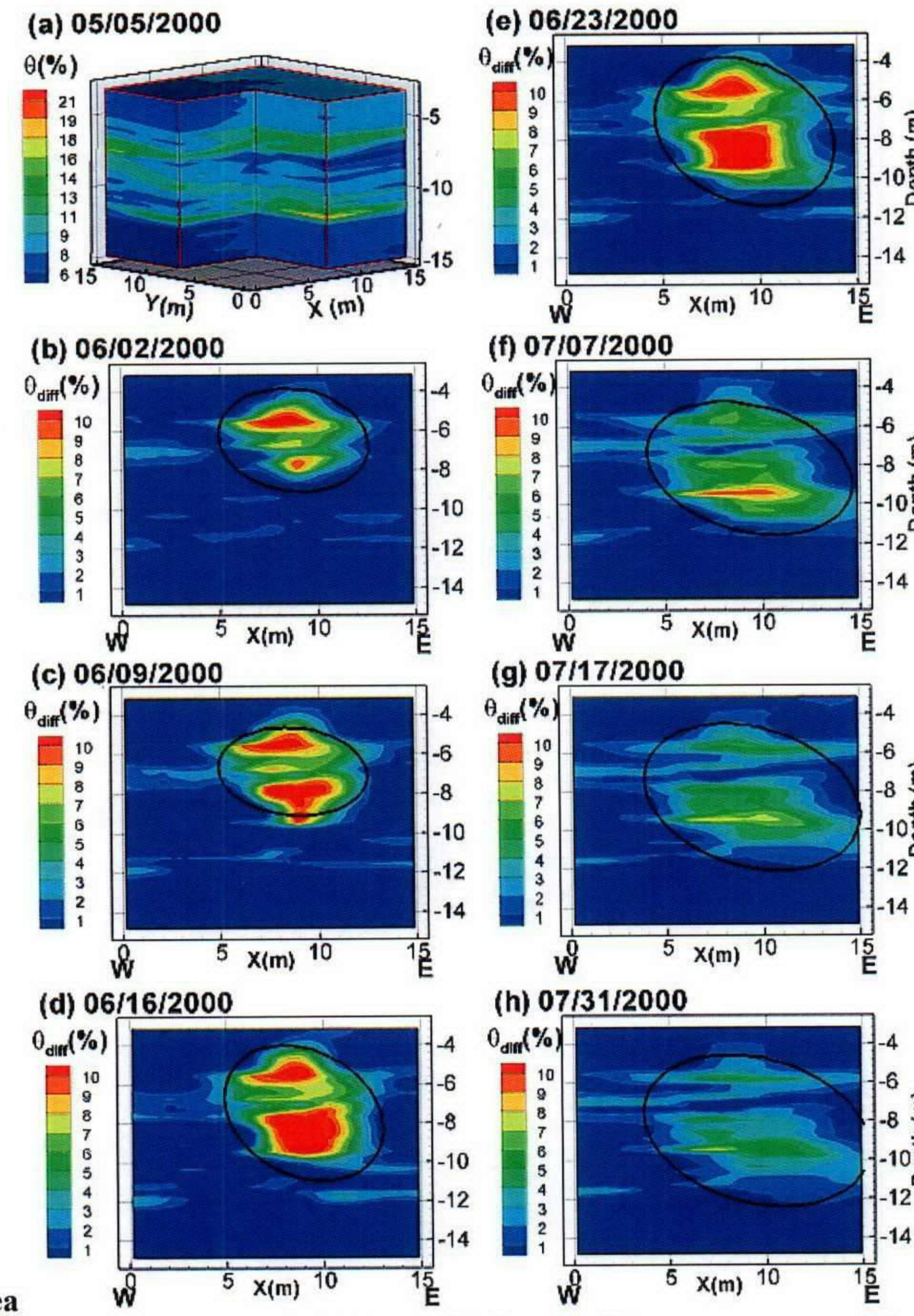
Note: The distance between neighboring circles is 1m, as indicated on the upper right corner of the figure. The lithostratigraphic cross section along B-B' is shown in Figure A-3.

Figure A-3. Lithostratigraphic cross section through the southeastern portion of the injection site (after Last et al., 2001).



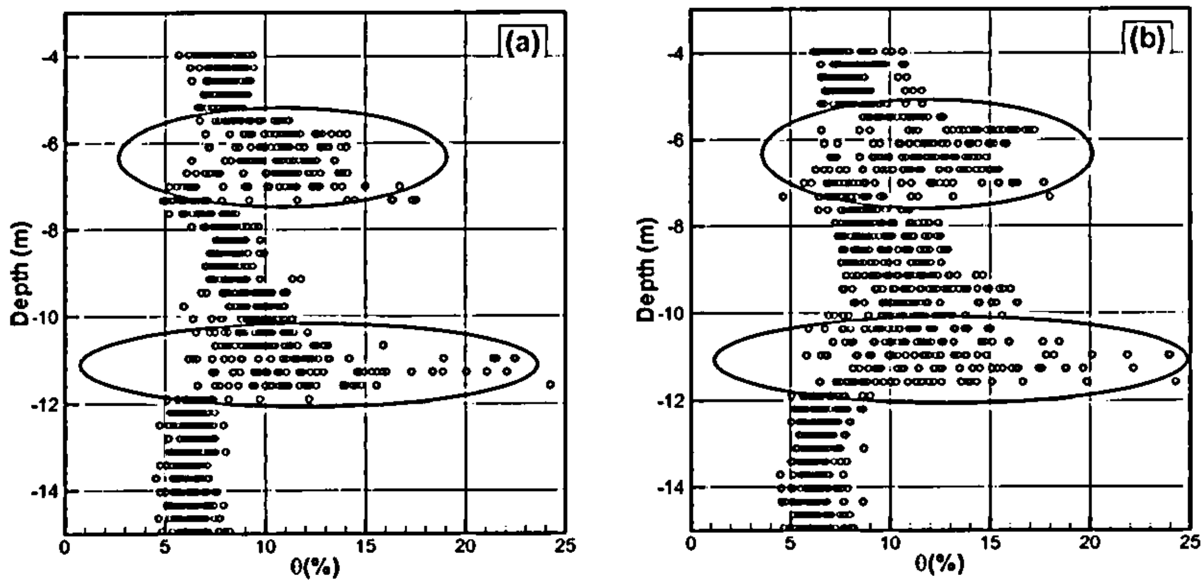
Note: The location of cross-section B-B' is shown in Figure A-2.

Figure A-4. Moisture Content Profiles for the Field Injection Experiment in the 200 East Area



(a) Initial moisture content on May 5, 2000 and (b) through (h) are east-west trending cross-sectional views of moisture content (θ) differences (measured θ – initial θ) along the plane passing through the injection well. The solid curves are the fitted ellipsoids.

Figure A-5. Moisture content (volume %) profiles measured on (a) May 5, 2000 and (b) July 31, 2000.



In earlier years, a number of vadose zone flow and transport experiments were reported at the Hanford Site and elsewhere (Trautwein et al. 1983; Routson et al. 1979; Price et al. 1979; Crosby et al. 1968, 1971; Prill 1977; Knoll and Nelson 1962; Palmquist and Johnson 1962; Wierenga et al. 1991a,b). As concluded in these studies, lateral movement of water and solutes is usually significant if the vadose zone medium is stratified, the initial moisture content is low, the size of the application area is small relative to the size of the unsaturated zone, and the application rate is small (Gelhar et al. 1985). These conclusions were qualitative but they provided the motivation and basis for subsequent theoretical work by Gelhar and his colleagues using a stochastic framework (e. g., Gelhar 1993; Yeh et al. 1985a, b and c; Mantoglou and Gelhar 1987; Ababou 1988; Polmann et al. 1991). This theoretical work led to the development of stochastic methods for quantifying the dynamics of moisture plume movement in heterogeneous media and also in estimating effective unsaturated media hydraulic properties [see Khaleel et al. 2002, Yeh et al. 2005 and Yeh et al. 2005 for further details on Hanford Site specific work].

Extrapolation of Plume Data from the Sisson and Lu Site.

The goal of the subsequent analysis was to transpose the series of experimentally derived plumes to a location under a hypothetical 100-series tank such that the data from the water injections would mimic a series of 4,000 L "tank leaks". The experimental water injections were made near the center of an array of monitoring wells. Figure A-6b shows how the array of wells was transposed such that the center of the moisture plume would coincide with the edge of a 100-series tank. From the soil-moisture data it is clear a "wetted zone" developed in the vicinity of the injection point (see Figure A-7b). It appears that a wetted zone developed at the point of injection, and the moisture mounded up to within 2 ft of the surface during the field test. The bottom of the "tank" was superimposed approximately 4 ft into the well array, thus, simulating a leak in the sidewall near the base.

Figure A-7a shows the moisture content of the soil at the Sisson and Lu site prior to any water injections. The importance of the pre-injection data is they show a high-moisture zone approximately 7 m (23 ft) below ground surface (bgs) that appears to be near saturation. A second moist zone is shown approximately 2.8 m (8 ft) bgs. In the series of figures projecting simulated tank leaks, the plumes represent the change in moisture content (i.e., measured 0 – initial 0) shortly after an injection relative to the pre-injection moisture content (initial 0).

Figure A-6c shows the moisture plume situated at the edge of the tank after the injection of 4,000 L of water and Figure 6d shows moisture data after the third 4,000-L injection. These two figures provide some prospective of the 3-dimensional nature of the plume and of "plume growth" with the addition of fluids.

Figures A-7a and A-7c provide a comparison of initial moisture conditions in the soil (i.e., before any water injections) with the soil moisture 5 weeks after the last of the five 4,000-L injections. From these figures it is clear the soil moisture content is rapidly returning to its initial condition.

Figures A-7b and A-7d provide a comparison between total moisture in the soil shortly after a 4,000-L injection (7b) and the difference between measured moisture at time t minus the initial soil moisture.

Figures A-8a through A-8d provide a plan view of the moisture plume at various times. After the injection of 16,000 L the plume reached the edge of the monitoring well array. By the fifth week after the last injection the plume expanded well beyond the monitoring well system. Figure A-8d shows a moisture plume that appears to exceed 15 m (~50 ft) diameter. This represents the maximum spread likely to be seen with a 20,000 L (5,300 gal) leak. With configuration of drywells around most of the SSTs, a leak of this magnitude would likely have been detected if the lost fluids contained mobile gamma emitters (i.e., ^{106}Ru and/or ^{60}Co). Thus, a 5,000-gal leak volume is suggested as the "minimum leak volume" that could be detected in drywells near SSTs or the maximum leak volume that would not be detected in a drywell. For tanks with laterals directly under the tank and high activity waste it was assumed that the maximum undetected leak volume would be 1,000 gallons.

There are several limitations to this "maximum undetected leak volume". Because the gamma logging-based leak detection system depended on the presence of mobile gamma-emitting radionuclides, the 5,000-gal volume estimate applies to high-activity waste types such as the REDOX and PUREX HLW streams and B Plant isotope recovery waste streams. The gamma-logging systems were of little value in detecting leaks of LAW types such as the 224 waste and aluminum cladding waste, which contained orders of magnitude less gamma emitters. Although fine-soil horizons are ubiquitous across the 200 East and West areas, the size, depth and properties of the fine-soil zones are site specific. Therefore a given site may have more or less horizontal spreading compared to the Sisson and Lu site. Finally, follow-up tests at the Sisson & Lu site indicated that fluid spreading in the vadose zone is sensitive to the salt content of the injected material. Additional tests are planned in the S tank farm to better evaluate these phenomena.

As discussed previously, other field data such as tank T-106 leak data support the concept of extensive lateral spread of tank waste fluids. A 1973 leak of approximately 115,000 gal of B Plant cesium recovery waste from SST T-106 was extensively characterized (RHO-ST-14, *High-Level Waste Leakage from the 241-T-106 Tank at Hanford*). The mobile ^{106}Ru plume spread laterally to encompass an oval-shaped area of approximately 140 ft by 170 ft. The vertical spread was approximately 50 ft below the apparent leak point. The leak event is believed to have lasted 71 days for an estimated leak rate of 1.1 gal/min (4 L/min). This leak rate compares with an approximate 2.9 gal/min injection rate for the field test. The ratio of lateral to vertical spread appears to be approximately 2 for the field test and 3 for the SST T-106 leak event. Given the differences in location, fluid discharge rate, and fluid compositions involved, this is good agreement.

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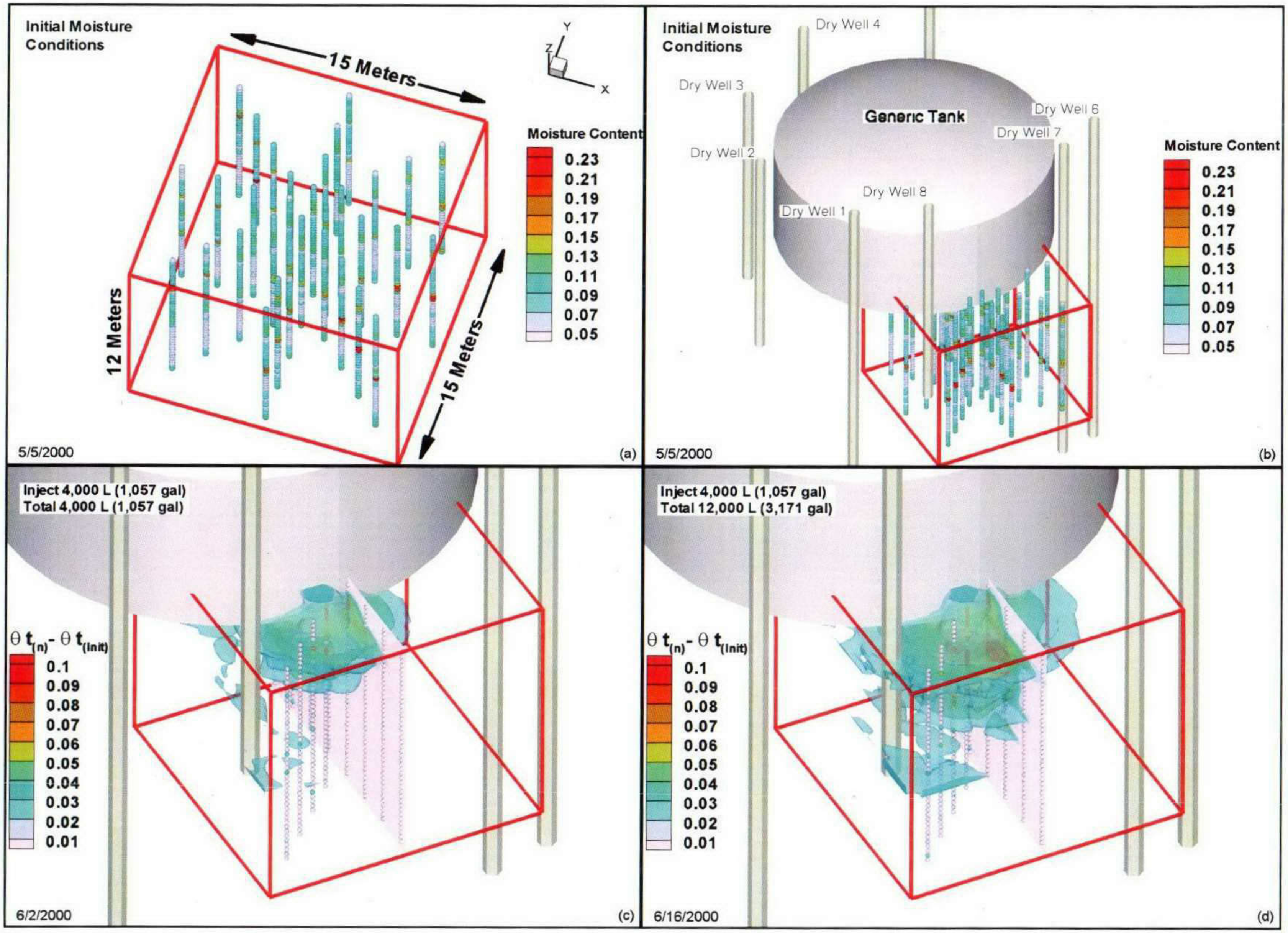

Figure A-6. Monitoring Wells and Moisture Content.

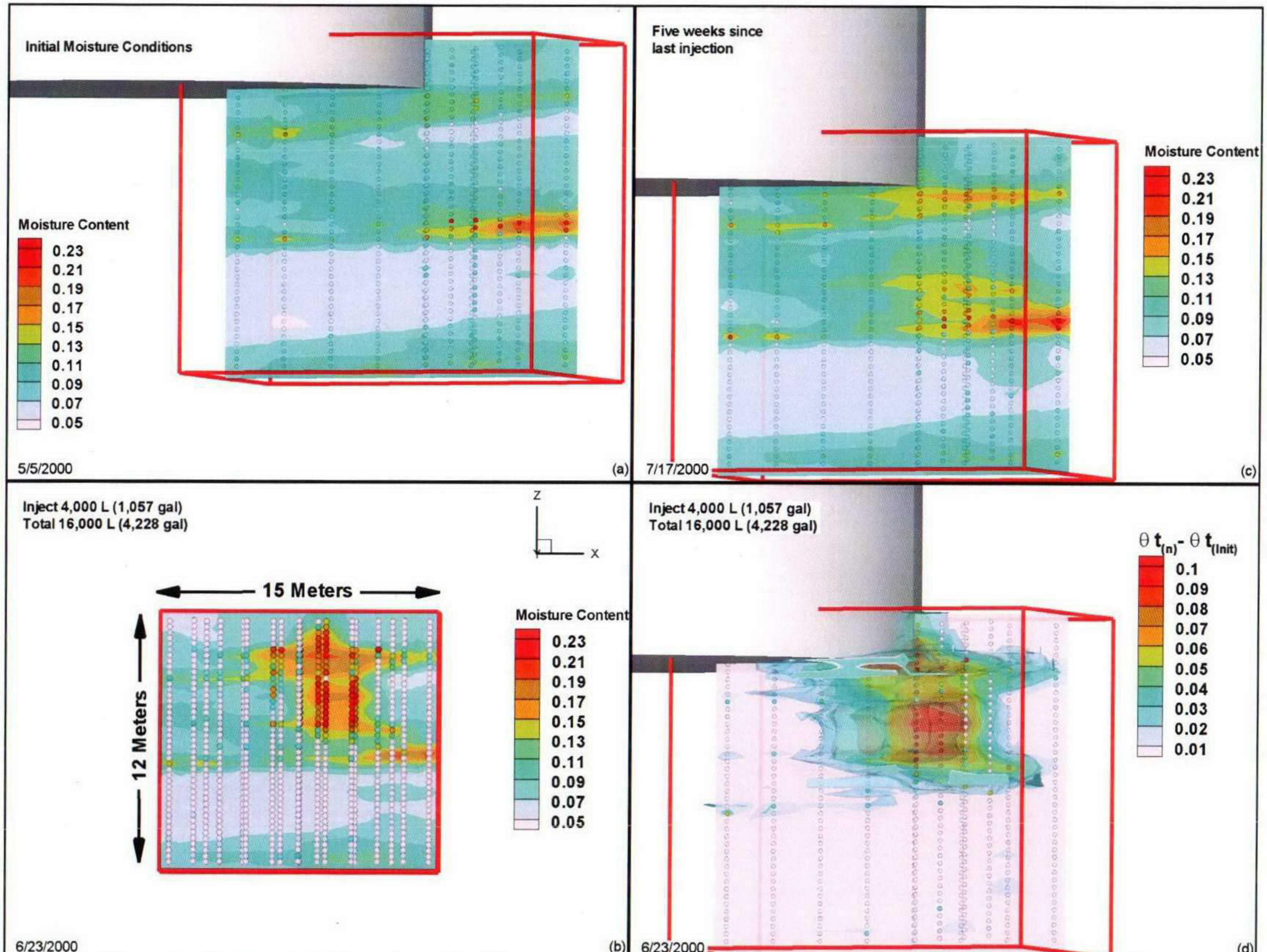

Figure A-7. Moisture Plume at Various Times.

Figure A-8. Plan View of Moisture Plume at Various Times.